Review

Applications of Clinical Decision Support Systems in Diabetes Care: Scoping Review

Shan Huang[1], MMed, MD; Yuzhen Liang[2], MD, PhD; Jiarui Li[3], MMed; Xuejun Li[4,5,6], MD, PhD

[1]Endocrinology Department, Tongren Hospital, Shanghai Jiao Tong University School of Medicine, Shanghai, China

[2]Department of Endocrinology, The Second Affiliated Hospital, Guangxi Medical University, Nanning, China

[3]Department of Endocrinology, Cangzhou Central Hospital, Cangzhou, China

[4]Department of Endocrinology and Diabetes, The First Affiliated Hospital of Xiamen University, School of Medicine, Xiamen University, Xiamen, China

[5]Xiamen Diabetes Institute, Xiamen, China

[6]Fujian Provincial Key Laboratory of Translational Medicine for Diabetes, Xiamen, China

Corresponding Author:
Xuejun Li, MD, PhD
Department of Endocrinology and Diabetes, The First Affiliated Hospital of Xiamen University
School of Medicine, Xiamen University
55 Zhenhai Road
Xiamen, 361003
China
Phone: 86 592 2137710
Email: xmlixuejun@163.com

Abstract

Background: Providing comprehensive and individualized diabetes care remains a significant challenge in the face of the increasing complexity of diabetes management and a lack of specialized endocrinologists to support diabetes care. Clinical decision support systems (CDSSs) are progressively being used to improve diabetes care, while many health care providers lack awareness and knowledge about CDSSs in diabetes care. A comprehensive analysis of the applications of CDSSs in diabetes care is still lacking.

Objective: This review aimed to summarize the research landscape, clinical applications, and impact on both patients and physicians of CDSSs in diabetes care.

Methods: We conducted a scoping review following the Arksey and O'Malley framework. A search was conducted in 7 electronic databases to identify the clinical applications of CDSSs in diabetes care up to June 30, 2022. Additional searches were conducted for conference abstracts from the period of 2021-2022. Two researchers independently performed the screening and data charting processes.

Results: Of 11,569 retrieved studies, 85 (0.7%) were included for analysis. Research interest is growing in this field, with 45 (53%) of the 85 studies published in the past 5 years. Among the 58 (68%) out of 85 studies disclosing the underlying decision-making mechanism, most CDSSs (44/58, 76%) were knowledge based, while the number of non-knowledge-based systems has been increasing in recent years. Among the 81 (95%) out of 85 studies disclosing application scenarios, the majority of CDSSs were used for treatment recommendation (63/81, 78%). Among the 39 (46%) out of 85 studies disclosing physician user types, primary care physicians (20/39, 51%) were the most common, followed by endocrinologists (15/39, 39%) and nonendocrinology specialists (8/39, 21%). CDSSs significantly improved patients' blood glucose, blood pressure, and lipid profiles in 71% (45/63), 67% (12/18), and 38% (8/21) of the studies, respectively, with no increase in the risk of hypoglycemia.

Conclusions: CDSSs are both effective and safe in improving diabetes care, implying that they could be a potentially reliable assistant in diabetes care, especially for physicians with limited experience and patients with limited access to medical resources.

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Introduction

In 2021, the International Diabetes Federation (IDF) reported that around 537 million adults worldwide had diabetes [1], resulting in 6.7 million related deaths and US $966 billion ($1838.40 per capita) in total health expenditure [2]. Achieving target glucose levels for the treatment of diabetes can be challenging, as patients might lack knowledge about their condition and health care providers (HCPs) might face limitations, such as inadequate information, time, and support for making decisions [3,4]. Poor glycemic control can lead to an elevated propensity for complications associated with diabetes and cardiovascular disease (CVD) events, ultimately resulting in a reduction in life expectancy [5-10]. Combined with the rising prevalence of diabetes [1,2] and a scarcity of specialized endocrinologists [11], the use of clinical decision support systems (CDSSs) in diabetes care has become increasingly necessary to improve the health care of patients with diabetes.

CDSSs are defined as "technology-based systems that intend to improve health care delivery by enhancing medical decisions with targeted clinical knowledge, patient information, and other health information" [12]. According to their decision-making mechanisms, CDSSs are commonly classified into knowledge- or non-knowledge-based systems. The decision-making mechanism of knowledge-based CDSSs is based on explicit, predetermined knowledge rules or guidelines [13], whereas non-knowledge-based CDSSs use artificial intelligence (AI) or machine learning (ML) algorithms to transform large-scale health care data into meaningful information for users to make decisions [12,14]. Several reviews have been published, discussing the applications of CDSSs in the field of diabetes care. Some reviews in which only randomized controlled trials (RCTs) were included addressed precise questions, such as the effectiveness of CDSSs in diabetes care [15,16]. Some reviews focused on the use of CDSSs in specific patients or settings, such as inpatients with diabetes in the noncritical care setting [17,18], patients with type 1 diabetes [19-21], and patients with type 2 diabetes in primary care [22]. However, a comprehensive analysis of the application of CDSSs in diabetes care is still lacking.

Although CDSSs are a rapidly adopted and emerging technology in the field of diabetes care, some HCPs are still relatively unfamiliar with them in terms of applications in managing and treating diabetes [23]. CDSSs can promote diabetes care by facilitating patient self‐management [24] and improving the process of medication management [19]. Obtaining a comprehensive understanding of their current applications is critical, which could provide valuable insights to enable further development and optimal use of CDSSs in diabetes care. Therefore, we conducted a scoping review (ScR) with the aim of summarizing the landscape of the research status, clinical applications, and impact of CDSSs on both patients and physicians in diabetes care. ScRs synthesize information across a range of study types and designs and provide a broad overview of a topic [25,26]. Therefore, an ScR was more suitable for our study objective compared to systematic reviews, which focus on addressing more specific questions based on particular criteria of interest.

Methods

Study Design

The methodology of this ScR was based on the method described by Arksey and O'Malley [27], and the report followed the PRISMA-ScR (Preferred Reporting Items for Systematic Reviews and Meta-Analyses Extension for Scoping Reviews) guidelines. The protocol was developed and registered in the International Platform of Registered Systematic Review and Meta-analysis Protocols (INPLASY; #202290061).

Determining the Research Question

This ScR aimed to answer 3 research questions (RQs):

- RQ1: What are the research characteristics of the applications of CDSSs in diabetes care?
- RQ2: What are the characteristics and clinical applications of CDSSs in diabetes care?
- RQ3: What is the impact of using CDSSs in diabetes care, and how can the impact be evaluated?

Identifying Relevant Studies

This study aimed to include all relevant literature and conference abstracts in English or Chinese. To identify relevant studies, an extensive search was conducted across 7 electronic databases: PubMed, Embase, the Cochrane Library, the Web of Science, the China National Knowledge Infrastructure (CNKI), Wanfang, and VIP. All searches were performed from the date of database establishment up to June 30, 2022. In addition, searches of additional sources, such as Google, Baidu, and official conference websites, were conducted for academic conference abstracts from the period of 2021-2022. Details are listed in Multimedia Appendix 1.

Study Selection

Studies were included if they reported the clinical application of CDSSs in diabetes care. CDSSs in this ScR referred to any technology-based systems (ie, mobile/tablet, web-based, or computer-based app) that can provide support for clinical decision-making and be applied across the whole spectrum of diabetes care, such as CDSSs used for treatment recommendation, complication risk assessment, and blood glucose monitoring.

The exclusion criteria were as follows:

- Studies published in languages other than Chinese or English
- Studies reporting CDSS technologies, algorithms, or theories and studies not directly pertaining to clinical decision support

- Studies not using clinical data (eg, genomic or protein data, or simulation data sets)
- Duplicate publications, research plans, reviews, commentaries, etc

Two researchers (authors XL and YL) independently evaluated the titles and abstracts of the identified studies based on the eligibility criteria. The full texts of potentially eligible studies were retrieved and then independently screened by the same 2 researchers (XL and YL). The 2 researchers also recorded the reasons for exclusion, and disagreements were resolved by a third senior researcher (author SH).

Data Charting

Two researchers (authors SH and JL) independently collected data using a standardized data sheet. Disagreements were resolved by a third researcher (XL). We collected the following variables that were pertinent to the aims of this research: (1) study characteristics (eg, publication year, number of subjects, follow-up period), (2) CDSS characteristics (eg, decision-making mechanism, functions) and clinical applications, and (3) evaluation of CDSSs in diabetes care (eg, user experience, user adherence, effectiveness and safety).

## Collating, Summarizing, and Reporting Results

Continuous variables were summarized into categories to allow for a more meaningful summary. Categorical variables were summarized using frequency counts and percentages. The number of papers reporting the corresponding outcome was used as the denominator for each variable.

Results

Search and Selection

A total of 11,569 studies were identified from included sources. After removing duplicated publications, 9607 (83%) studies were available for title and abstract screening. Finally, 237 (2.5%) studies were evaluated based on their full text, and 85 (35.9%) studies [23,28-111] (including 13/18, 15%, conference abstracts) were selected for analysis. The PRISMA-ScR flow diagram is shown in Figure 1 and the PRISMA-ScR checklist in Multimedia Appendix 2.

Figure 1. PRISMA-ScR flowchart demonstrating the study selection process. CDSS: clinical decision support system; PRISMA-ScR: Preferred Reporting Items for Systematic Reviews and Meta-Analyses.
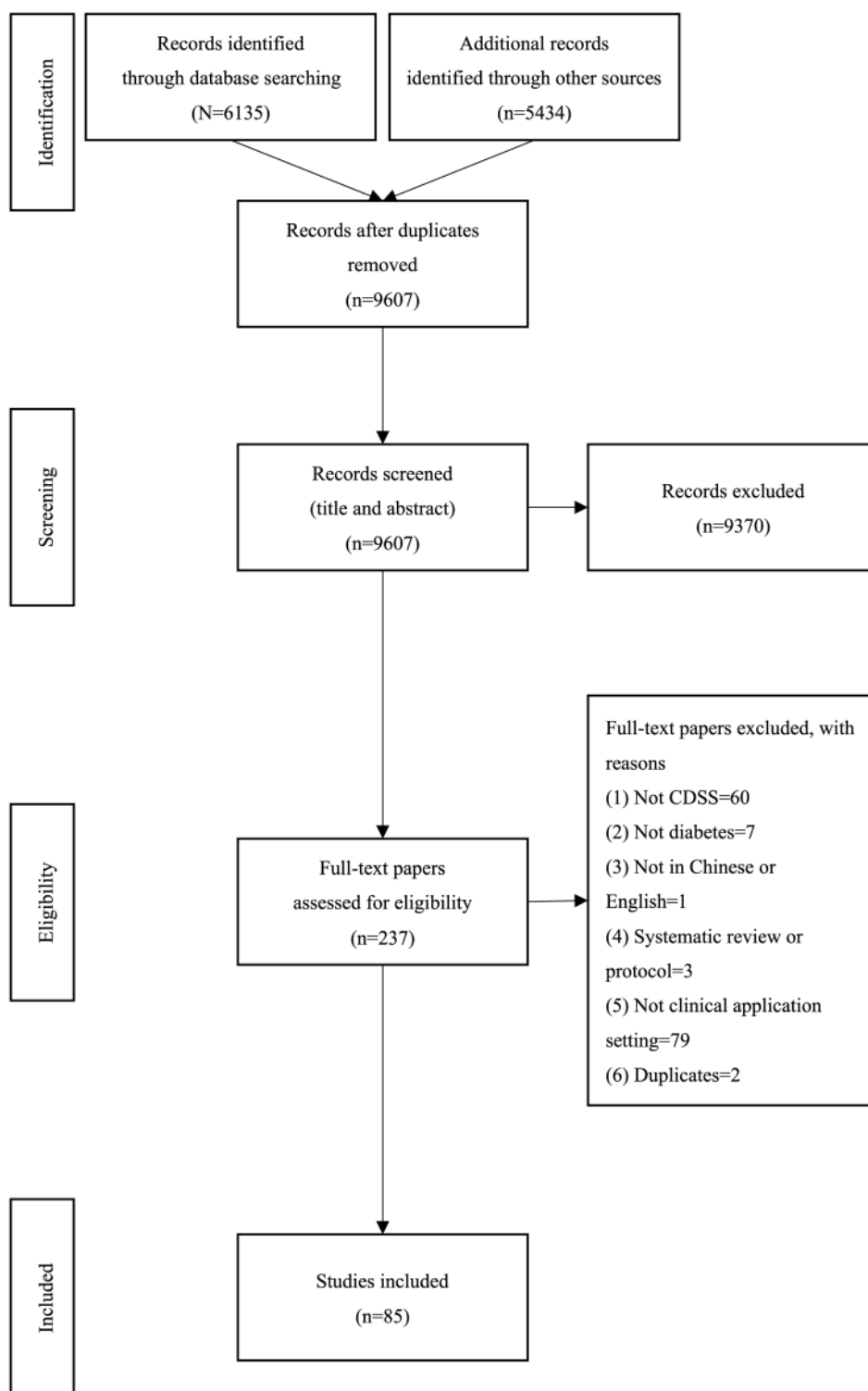
Study Characteristics

In the 85 studies included in this ScR, a total of 159,475 subjects were enrolled. The number of publications was undergoing rapid growth during 2021-2022, and 45 (53%) of the studies were published in the past 5 years (2018-2022), as shown in Multimedia Appendix 3). Tables 1-7 summarize the characteristics of the included studies. The most common

follow-up period was less than 12 months (<6 months: 20/75, 27%; 6-12 months: 38/75, 51%). The majority of studies were conducted in North American or European countries, with 34% (22/64) being conducted in the United States and 9% (6/64) in Austria and Germany. About half of the studies (34/65, 52%) were multicenter and 48% (31/65) were single-center studies. Most studies were RCTs (36/85, 42%), followed by single-arm

trials (22/85, 26%), observational studies (18/85, 21%), and   pragmatic clinical trials (PCTs; 5/85, 6%).

Table 1. Summary of study characteristics (N=85).

Characteristic and categories for each characteristic	Valid studies, n (%)[a,b]	References
Publication years		
1986-1992	3 (4)	[28-30]
1993-1997	3 (4)	[31-33]
1998-2002	3 (4)	[34-36]
2003-2007	8 (9)	[37-44]
2008-2012	9 (11)	[45-53]
2013-2017	14 (16)	[54-67]
2018-2022	45 (53)	[23,68-111]
Number of subjects		
<100	32 (38)	[28-30, 32-34, 36, 37, 43, 57, 60, 63, 64, 67-69, 71, 73, 77, 80, 88, 92, 95, 97-99, 102, 103, 106, 108-110]
100-500	24 (28)	[23, 39, 40, 42, 46, 48, 49, 51, 52, 56, 59, 61, 62, 65, 75, 82-84, 87, 90, 94, 100, 104, 111]
501-999	13 (15)	[31, 38, 41, 45, 53-55, 72, 91, 93, 101, 105, 107]
≥1000	16 (19)	[35, 44, 47, 50, 58, 66, 70, 74, 76, 78, 79, 81, 85, 86, 89, 96]

[a]Number of studies and percentages were presented. The percentages of valid, unspecified, and unapplicable studies were calculated within the total studies (N=85), while the percentages for each characteristic were calculated within the valid studies.

[b]Studies that reported the corresponding characteristics were considered valid studies.

Table 2. Summary of the baseline start year (N=85).

Characteristic and categories for each characteristic	Studies, n (%)[a]	References
Valid studies (n=43, 51%)[b]		
1993-1997	1 (2)	[35]
1998-2002	6 (14)	[38-42, 45]
2003-2007	3 (7)	[44, 47, 50]
2008-2012	8 (19)	[48, 49, 56, 58, 60, 70, 72]
2013-2017	15 (35)	[57, 61, 63, 66, 73, 75, 78, 81, 84, 85, 87, 90, 93, 98, 108]
2018-2022	10 (23)	[23, 79, 80, 83, 86, 96, 101, 103, 105, 107]
Unspecified studies	41 (48)	[28-34, 36, 37, 43, 46, 51-54, 59, 62, 64, 65, 67-69, 71, 74,76,77,82, 88, 89, 91, 92, 94, 95, 97, 99, 100, 102, 104, 106, 109, 111]
Unapplicable studies[c]	1 (1)	[110]

[a]Number of studies and percentages were presented. The percentages of valid, unspecified, and unapplicable studies were calculated within the total studies (N=85), while the percentages for each characteristic were calculated within the valid studies.

[b]Studies that reported the corresponding characteristics were considered valid studies.

[c]Computer simulation study.

Table 3. Summary of the follow-up period[a] (N=85).

Characteristic and categories for each characteristic	Studies, n (%)[b]	References
Valid studies (n=75, 88%)[c]		
<6 months	20 (27)	[28, 30, 32, 40, 43, 48, 52, 59, 63, 64, 69, 71, 77, 80, 83, 86, 97, 99, 104, 109]
6-11 months	38 (51)	[31, 33, 36-39, 41, 45-47, 49-51, 55-57, 61, 62, 65, 68, 74-76, 78, 81, 84, 85, 87, 88, 92, 95, 96, 100-102, 107, 108, 111]
12-24 months	10 (13)	[23, 29, 34, 35, 42, 44, 53, 79, 93, 98]
>24 months	7 (9)	[54, 58, 60, 66, 70, 72, 90]
Unspecified studies	6 (7)	[67, 73, 82, 89, 91, 94]
Unapplicable studies[d]	4 (5)	[103, 105, 106, 110]

[a]In 3 (4%) studies, the study design was a randomized controlled trial (RCT) cross-over; the follow-up period was defined as the overall study duration including the washout period for cross-over studies.

[b]Number of studies and percentages were presented. The percentages of valid, unspecified, and unapplicable studies were calculated within the total studies (N=85), while the percentages for each characteristic were calculated within the valid studies.

[c]Studies that reported the corresponding characteristics were considered valid studies.

[d]Computer simulation study and cross-sectional study.

Table 4. Summary of the country[a] (N=85).

Characteristic and categories for each characteristic	Studies, n (%)[b]	References
Valid studies (n=64, 75%)[c]		
United States	22 (34)	[23, 31, 33, 34, 41, 42, 50, 51, 55, 59, 66, 69, 70, 74, 79, 84-86, 98, 103, 104, 106]
Austria	6 (9)	[57, 60, 67, 73, 90, 94]
Germany	6 (9)	[30, 36, 43, 46, 84, 87]
China	5 (8)	[39, 63, 76, 101, 105]
South Korea	5 (8)	[40, 49, 61, 75, 103]
Spain	5 (8)	[53, 65, 88, 103, 107]
India	4 (6)	[58, 72, 78, 93]
United Kingdom	3 (5)	[32, 64, 88]
Canada	3 (5)	[45, 80, 108]
Israel	3 (5)	[84, 103, 104]
Belgium	2 (3)	[81, 103]
Netherlands	2 (3)	[44, 47]
Other[d]	16 (25)	[35, 44, 54, 56, 62, 72, 83, 84, 100, 103]
Unspecified studies	21 (25)	[28, 29, 37, 38, 48, 52, 68, 71, 77, 82, 89, 91, 92, 95-97, 99, 102, 109-111]

[a]Of the valid studies, 5 (8%) were cross-national studies; thus, the sum of percentages may exceed 100%.

[b]Number of studies and percentages were presented. The percentages of valid, unspecified, and unapplicable studies were calculated within total studies (N=85), while the percentages for each characteristic were calculated within the valid studies.

[c]Studies that reported the corresponding characteristics were considered valid studies.

[d]Brazil, France, Ireland, Japan, Italy, Norway, Russia, Sri Lanka, Croatia, Finland, Serbia, Greece, the Czech Republic, the United Arab Emirates, Pakistan, and Slovenia (1 study for each country).

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Table 5. Summary of the number of centers (N=85).

Characteristic and categories for each characteristic	Studies, n (%)[a]	References
Valid studies (n=65, 77%)[b]		
Multicenter	34 (52)	[23, 31, 35, 36, 43, 44, 47, 51-53, 58, 59, 62, 63, 65, 72, 74-77, 79-81, 83, 84, 88, 89, 98, 100, 103, 104, 106-108]
Single center	31 (48)	[30, 32-34, 38-42, 45,49, 50, 54-57, 60, 61, 64, 66-68, 70, 73, 78, 85, 87, 90, 94, 96, 105]
Unspecified studies	18 (21)	[28, 29, 37, 48, 69, 71, 82, 91-93, 95, 97, 99, 101, 102, 109-111]
Unapplicable studies[c]	2 (2)	[46, 86]

[a]Number of studies and percentages were presented. The percentages of valid, unspecified, and unapplicable studies were calculated within the total studies (N=85), while the percentages for each characteristic were calculated within the valid studies.

[b]Studies that reported the corresponding characteristics were considered valid studies.

[c]Database studies.

Table 6. Summary of the study design (N=85).

Characteristic and categories for each characteristic	Valid studies, n (%)[a,b]	References
Observational studies (n=18, 21%)		
Prospective cohort study	5 (28)	[23, 29, 72, 97, 107]
Retrospective cohort study	9 (50)	[46, 54, 55, 70, 86, 87, 91, 101, 102]
Ambispective cohort study	1 (6)	[65]
Cross-sectional study	3 (17)	[103, 105, 106]
RCTs[c] (n=36, 42%)		
Parallel design	23 (64)	[28, 30-33, 35, 36, 38-40, 42, 43, 49, 56, 61, 63, 74, 75, 80, 83, 84, 93, 98]
Cross-over design	3 (8)	[69, 71, 88]
Cluster RCT	10 (28)	[41, 47, 50-53, 66, 81, 85, 89]
PCT[d]	5 (6)	[44, 45, 59, 78, 108]
Single-arm trial	22 (26)	[34, 37, 48, 57, 58, 62, 64, 67, 68, 73, 76, 77, 79, 92, 94-96, 99, 100, 104, 109, 111]
Other[e]	4 (5)	[60, 82, 90, 110]

[a]Number of studies and percentages were presented. The percentages of valid, unspecified, and unapplicable studies were calculated within the total studies (N=85), while the percentages for each characteristic were calculated within the valid studies.

[b]Studies that reported the corresponding characteristics were considered valid studies.

[c]RCT: randomized controlled trial.

[d]PCT: pragmatic clinical trial.

[e]Post hoc analysis and computer simulation.

Table 7. Summary of the data source (N=85).

Characteristic and categories for each characteristic	Valid studies, n (%)[a,b]	References
Primary data	68 (80)	[23, 28-45, 47-53, 56-59, 61-69, 71-81, 83-85, 88, 89, 93, 94, 96-98, 101, 104-109, 111]
Secondary data (n=22, 26%)		
EHR[c]	10 (36)	[48, 54, 55, 65, 90-92, 100, 102, 103]
Devices	6 (27)	[87, 95, 99, 101, 103, 108]
Clinical trials	4 (18)	[60, 82, 90, 110]
Surveys	3 (14)	[46, 48, 62]
Patient-reported outcomes	2 (9)	[45, 70]
Registry	1 (5)	[46]

[a]Number of studies and percentages were presented. The percentages of valid, unspecified, and unapplicable studies were calculated within the total studies (N=85), while the percentages for each characteristic were calculated within the valid studies.

[b]Studies that reported the corresponding characteristics were considered valid studies.

[c]EHR: electronic health record.

Characteristics and Clinical Applications of CDSSs in Diabetes Care

The characteristics of CDSSs are summarized in Table 8. Most CDSSs included in this ScR were knowledge based (44/58, 76%), although non-knowledge-based CDSSs have been increasing in recent years. In 59% (48/82) of the studies, physicians were the users of CDSSs. In 51% (42/82) of the studies, patients were the users of CDSSs. Both physicians and patients were the users of CDSSs in 10% (8/82) studies. In 30% (25/82) of the studies, nurses, medical assistants, and pharmacists supported physicians in using CDSSs. The types of outputs provided by CDSSs were vast, and we classified them based on the 6 categories of intervention types reported in the *Clinical Decision Support Implementers' Workbook* [112]. Most CDSSs facilitated users by providing proactive order suggestions and order sets (65/83, 78%) and supporting guidelines, complex protocols, algorithms, and clinical pathways (25/83, 30%).

Table 8. Summary of CDSS[a] characteristics.

Characteristic and categories for each characteristic	Studies, n (%)[b]	References
Decision-making mechanism[c]: valid studies[d] (n=58, 68%)		
Knowledge based	44 (76)	[23, 28, 30-33, 35, 36, 38, 40, 42-47, 49, 50, 53, 54, 58, 59, 61, 65, 66, 70, 72, 74, 78, 79, 81, 83, 96, 97, 100, 106, 108, 109]
Non-knowledge based	14 (24)	[37, 57, 64, 69, 71, 73, 80, 84, 85, 88, 103-105, 107]
Decision-making mechanism: unspecified studies	27 (32)	[29, 34, 39, 41, 48, 51, 52, 55, 60, 62, 63, 68, 75, 77, 82, 86, 89, 91-93, 95, 98, 99, 101, 102, 110, 111]
Setting: valid studies (n=73, 86%)		
Primary care	29 (40)	[23, 28, 29, 33, 35, 42, 44, 45, 47, 50, 52-55, 58, 59, 62, 63, 65, 66, 74, 78, 79, 81, 83, 85, 89, 104, 106]
Specialized hospital	23 (32)	[31, 34, 38-40, 43, 56, 57, 60, 67, 73, 76, 77, 82, 84, 90, 94, 96, 97, 102, 103, 105, 107]
Diabetes center	6 (8)	[30, 32, 68, 69, 72, 87]
Household	15 (21)	[37, 49, 51, 61, 64, 75, 88, 92, 93, 95, 98, 99, 101, 108, 109]
Setting: unspecified studies	12 (14)	[36, 41, 46, 48, 70, 71, 80, 86, 91, 100, 110, 111]
Target patient (type of diabetes): valid studies (n=85, 100%)		
Type 2 diabetes	42 (49)	[23, 38-41, 44, 45, 47, 49-54, 57, 59-63, 65-67, 72, 73, 75, 76, 78, 79, 81-83, 87, 90-94, 97, 102, 105, 107, 111]
Type 1 diabetes	20 (24)	[28, 29, 34, 36, 37, 64, 69, 71, 80, 84, 86, 88, 95, 98, 99, 101, 103, 104,109, 110]
Gestational diabetes	1 (1)	[100]
Multiple types[e]	17 (20)	[30-33, 35, 42, 43, 46, 48, 55, 58, 68, 70, 74, 85, 96, 108]
Other[f]	5 (6)	[56, 77, 89, 106]
Target patient (age group [years]): valid studies (n=71, 84%)		
<20	5 (7)	[66, 80, 84, 95, 103]
[20,40)	9 (13)	[30, 32, 34, 36, 37, 69, 86, 101, 110]
[40,50)	7 (10)	[28, 29, 43, 56, 64, 71, 88]
[50,60)	18 (25)	[40, 48, 51, 54, 55, 59, 65, 68, 70, 75, 78, 83, 85, 89, 91, 93, 98, 108]
≥60	32 (45)	[35, 38, 39, 41, 42, 44-47, 49, 53, 57, 60-63, 67, 73, 74, 77, 79, 81, 82, 87, 90, 92, 94, 96, 102, 105, 107, 111]
Target patient (age group): unspecified studies	14 (16)	[23, 31, 33, 50, 52, 58, 72, 76, 97, 99, 100, 104, 106, 109]
User type: valid studies (n=82, 96%)		
Patient	42 (51)	[28-30, 36, 37, 39-42, 45, 49, 51, 54, 56, 59, 61, 63-65, 68-71, 75, 84, 86-89, 91-93, 95, 98, 99, 101, 104, 106, 108-111]
HCP[g]	48 (59)	[23, 32-35, 38, 42-48, 50, 52-55, 57, 58, 60, 62, 66, 67, 69, 70, 72-74, 76-81, 83-85, 89, 90, 94, 96, 97, 103, 105-107]
Physician only	23 (28)	[31, 35, 43, 45, 46, 53-55, 66, 67, 69, 70, 76, 80, 81, 84, 85, 89, 96, 97, 103, 105, 107]
Physician assisted by nurses, medical assistants, and pharmacists	25 (30)	[23, 32-34, 38, 42, 44, 47, 48, 50, 52, 57, 58, 60, 62, 72-74, 77-79, 83, 90, 94, 106]
User type: unspecified studies	3 (4)	[82, 100, 102]
Function[h]: valid studies (n=83, 98%)		
Forms and templates	9 (11)	[31, 33, 41, 44, 52, 62, 66, 88, 108]
Relevant data presentation	24 (29)	[31, 34, 40, 41, 49, 51, 52, 54, 61-63, 66, 71, 76, 84, 85, 87, 88, 96, 98, 101, 105-107]

Characteristic and categories for each characteristic	Studies, n (%)[b]	References
Proactive order suggestions and order sets	65 (78)	[23, 28-30, 32, 33, 35-50, 53, 54, 56-58, 60-62, 64, 65, 67-69, 72-84, 86, 88-90, 93-95, 97-99, 102-104, 106, 108-110]
Support for guidelines, complex protocols, algorithms, clinical pathways	25 (30)	[31, 33, 35, 38, 40, 43-46, 50, 51, 53, 54, 61, 66, 72, 74, 76, 78, 81, 83, 87, 88, 96, 109]
Reactive alerts	15 (18)	[31, 33, 38, 45, 49, 54, 61, 62, 70, 78, 81, 84, 93, 96, 108]
Reference information and guidance	14 (17)	[33, 35, 42, 51, 54, 59, 61, 63, 81, 83, 91, 93, 101, 111]
Function: unspecified studies	2 (2)	[55, 100]

[a]CDSS: clinical decision support system.

[b]Number of studies and percentages were presented. The percentages of valid, unspecified, and unapplicable studies were calculated within the total studies (N=85), while the percentages for each characteristic were calculated within the valid studies.

[c]Knowledge-based CDSSs used explicit, predetermined knowledge rules or guidelines [13], whereas non-knowledge-based CDSSs used artificial intelligence (AI) or machine learning (ML) algorithms.

[d]Studies that reported the corresponding characteristics were considered valid studies.

[e]Patients had both type 1 and type 2 diabetes.

[f]Healthy adults with a family history of type 2 diabetes, critically ill patients with hyperglycemia, or adults with prediabetes.

[g]HCP: health care provider.

[h]We classified the studies on CDSS use in diabetes care based on the 6 categories of intervention types reported by Osheroff et al [112]. Some studies combined several CDSS intervention types and therefore are represented in multiple categories.

Users could leverage CDSSs in the clinical management of diabetes in various ways (Table 9). The most common application scenario of CDSSs was to provide treatment recommendations (63/81, 78%), not only for physicians (36/47, 77%), but also for patients (29/42, 69%). Of the 36 (77%) studies, CDSSs were commonly used by physicians for drug recommendations (n=22, 61%) and insulin dose adjustment (n=14, 39%). Of the 29 (69%) studies, CDSSs were used by patients not only for insulin dose adjustment (n=16, 55%) and drug recommendations (n=6, 21%) but also for suggestions for diet and exercise (n=11, 38%). Other application scenarios included medical education (13/81, 16%), complication risk assessment (12/81, 15%), blood glucose monitoring (12/81, 15%), diabetes screening (4/81, 5%), and appointments for examinations (3/81, 4%). When categorizing physician users according to their medical disciplines, primary care physicians (20/39, 51%) were the most common, followed by endocrinologists (15/39, 38%) and nonendocrinologists (8/39, 21%). For primary care physicians as users in 20 (51%) studies, CDSSs were mainly used for treatment recommendations (n=16, 80%) and no application scenario for blood glucose monitoring was found. For endocrinologists as users in 15 (38%) studies, CDSSs were mainly used for treatment recommendations (n=13, 87%) and no application scenarios for medical education, appointments for examinations, and diabetes screening were found. For nonendocrinologists as users in 8 (21%) studies, CDSSs were only used for treatment recommendations (n=4, 50%), complication risk assessment (n=3, 38%), and diabetes screening (n=1, 13%).

Table 9. Clinical applications of CDSSs[a] in diabetes care by user.

Clinical application	All users[b] (n=81)	Physicians as users				Patients as users
		All physicians (n=47)	Medical discipline[c]: primary care (n=20)	Medical discipline: specialist endocrinology (n=15)	Medical discipline: specialist nonendocrinology[d] (n=8)	All patients (n=42)
Treatment recommendations	63 (78)	36 (77)	16 (80)	13 (87)	4 (50)	29 (69)
Insulin dose adjustment	30 (48)	14 (39)	1 (6)	9 (69)	3 (75)	16 (55)
Drug recommendations[e]	27 (43)	22 (61)	15 (94)	4 (31)	1 (25)	6 (21)
Suggestions for diet and exercise	11 (17)	1 (3)	1 (6)	0	0	11 (38)
Complication risk assessment[f]	12 (15)	9 (19)	4 (20)	2 (13)	3 (38)	4 (10)
Medical education	13 (16)	4 (9)	3 (15)	0	0	10 (24)
Appointments/alerts of examinations	3 (4)	3 (6)	1 (5)	0	0	2 (5)
Diabetes screening in high-risk population	4 (5)	4 (9)	3 (15)	0	1 (13)	1 (2)
Blood glucose monitoring	12 (15)	1 (2)	0	1 (7)	0	11 (26)

[a]CDSS: clinical decision support system.

[b]Of the 85 studies included, 3 (4%) with missing information on user type and 1 (1%) with missing information on specific clinical application were excluded from the analysis. Numbers of studies and percentages are presented. Some CDSSs were used in multiple clinical applications. The percentages of subcategories of treatment recommendations were calculated within treatment recommendations. Both physicians and patients were users of CDSSs in 10% (8/81) studies.

[c]Of 47 studies, 39 (83%) reported the medical discipline of physicians and 8 (17%) reported missing relevant information about medical disciplines; Physicians were from multiple disciplines in 4 (10%) of 39 studies.

[d]Ophthalmology, neurology, cardiology, surgery, the emergency department, the intensive care unit, and pediatrics.

[e]Recommendations for antidiabetic drugs, antihypertensive drugs, and lipid-lowering drugs.

[f]Complications include cardiovascular disease (CVD), diabetes retinopathy, diabetes foot, renal failure, hyperglycemia, and hypoglycemia.

Evaluation of CDSSs in Diabetes Care

CDSSs in diabetes care have been evaluated using various dimensions, including the effectiveness, safety, consistency, and diagnostic accuracy of CDSSs; user behavior, user adherence, and user experience; and cost-effectiveness. Studies that evaluated the effectiveness and safety of CDSSs regarding biomarkers were the most prevalent, and the results of the effectiveness of CDSSs for biomarkers are summarized in Table 10. Regarding the safety of using CDSSs, the risk of hypoglycemia significantly decreased in 34% (12/35) studies [36,49,60,61,67,69,73,82,86,87,98,110].

Table 10. Summary of the effectiveness (64/85, 75%) of CDSSs[a] for biomarkers.

Outcomes	Studies that showed CDSSs significantly improved outcomes, n/N (%)[b]	References
Blood glucose	45/63 (71)	[23, 28-30, 32, 34, 36, 39, 42-46, 48-51, 53, 54, 57, 58, 61, 62, 65, 68, 69, 73-75, 78, 79, 82, 84, 86, 87, 90-94, 98, 101, 102, 104, 110]
HbA1c[c]	30/43 (70)	[23, 28, 29, 34, 36, 39, 42-46, 49-51, 53, 54, 61, 62, 65, 68, 74, 75, 78, 79, 84, 86, 87, 91, 92, 98]
FBG[d]	4/9 (44)	[39, 58, 93, 101]
MBG[e]	8/14 (57)	[30, 32, 36, 43, 46, 82, 90, 102]
TIR[f]	12/18 (67)	[48, 57, 73, 82, 87, 90, 94, 98, 101, 102, 104, 110]
GV[g]	5/7 (71)	[36, 46, 48, 69, 87]
Blood pressure	12/18 (67)	[35, 42, 44, 45, 47, 50, 58, 61, 63, 65, 72, 78]
SBP[h]	11/18 (61)	[42, 44, 45, 47, 50, 58, 61, 63, 65, 72, 78]
DBP[i]	10/15 (67)	[35, 42, 44, 45, 47, 50, 58, 63, 65, 72]
Blood lipid	8/21 (38)	[39, 42, 44, 47, 61, 65, 72, 74]
LDL[j] cholesterol	6/15 (40)	[39, 44, 47, 65, 72, 74]
HDL[k] cholesterol	1/7 (14)	[39]
TC[l]	4/11 (36)	[39, 44, 47, 61]
TG[m]	2/5 (40)	[39, 42]

[a]CDSS: clinical decision support system.

[b]The results were represented as the ratio of the number of studies with a significant improvement in outcomes to the number of studies with related indicators.

[c]HbA1c: glycated hemoglobin.

[d]FBG: fasting blood glucose.

[e]MBG: mean blood glucose.

[f]TIR: time in range.

[g]GV: glucose variability.

[h]SBP: systolic blood pressure.

[i]DBP: diastolic blood pressure.

[j]LDL: low-density lipoprotein.

[k]HDL: high-density lipoprotein.

[l]TC: total cholesterol.

[m]TG: triglyceride.

Of the 85 studies included, 64 (75%) assessed the effectiveness of CDSSs in improving patients' blood glucose (n=63, 98%), blood pressure (n=18, 28%), and blood lipid levels (n=21, 33%). Significant improvements in biomarkers were based on the reported results of the included studies. A significant improvement in any 1 biomarker was considered significant. CDSSs significantly improved patients' blood glucose (45/63, 71%), blood pressure (12/18, 67%), and blood lipid (8/21, 38%) levels. Specifically, CDSSs significantly improved glycated hemoglobin (HbA1c; 30/43, 70%), glucose variability (GV; 5/7, 71%), diastolic blood pressure (DBP; 10/15, 67%), time in range (TIR; 12/18, 67%), systolic blood pressure (SBP; 11/18, 61%), and mean blood glucose (MBG; 8/14, 57%).

In addition, 35 (41%) studies evaluated the safety of CDSS use in diabetes care, indicating that CDSSs would not increase the risk of hypoglycemia. Meanwhile, CDSSs significantly decreased the risk of hypoglycemia in 34% (12/35) of the studies.

Furthermore, 3 (4%) studies analyzed the consistency of insulin dose adjustments determined between CDSS algorithms and physicians, suggesting that the recommendations made by CDSSs are like those made by physicians and have an acceptance rate of more than 90% among HCPs. Additionally, 2 (2%) studies demonstrated the diagnostic accuracy of CDSSs in predicting the risk of diabetic retinopathy.

Of the 85 studies included, 16 (19%) evaluated users' adherence and the results are summarized in Multimedia Appendix 4. In 7 (44%) studies, users' adherence to insulin dose suggestions was over 90%. In 7 (44%) studies, CDSSs improved users'

adherence to follow-up and examination appointments, diabetes care guidelines, and drug usage. In the remaining 2 (13%) studies, users' adherence to suggestions for lifestyle changes ranged from 50% to 80%.

In addition, 25 (29%) studies evaluated the user experience of CDSSs. All studies reported positive comments, with 9 (36%) also reporting negative comments. Users provided favorable comments for CDSSs, such as "It was easy to use" [81] and "It offered useful information" [62]. Meanwhile, challenges and limitations associated with using CDSSs were exposed by negative comments, for example, "Software glitches influenced physicians' acceptance of CDSSs" [23], "A lack of integration with the electronic health record (EHR) system would result in a more complicated workflow" [23], "Some recommendations provided by CDSSs did not consider comorbidities or patient adherence" [23], and "CDSSs were not up to date on the most recent guidelines" [72].

Discussion

Principal Findings

To the best of our knowledge, this is the first ScR to provide a comprehensive analysis of the use of CDSSs in diabetes care. Our findings suggest a significant increase in the number of studies and relevant study participants in recent years, reflecting a growing interest in using CDSSs in diabetes care. Most CDSSs are knowledge based, while the number of non-knowledge-based CDSSs has been increasing in recent years. CDSSs can be used by diverse users (even nonendocrinologists, nurses, medical assistants, and pharmacists) in various application scenarios, including treatment recommendations, medical education, complication risk assessment, blood glucose monitoring, appointments for examinations, and diabetes screening. The included studies demonstrated that CDSSs are effective and safe for diabetes care.

CDSSs Could Be Effective and Safe in Improving Diabetes Care

Studies assessing the effectiveness of CDSSs primarily used biomarkers (eg, HbA1c, TIR, or low-density lipoprotein [LDL]) as endpoints. The most common follow-up period in the included studies was less than 12 months. Our review found that CDSSs significantly improve blood glucose, blood pressure, and lipid profile (71%, 67%, and 38% of the studies, respectively) and that the risk of hypoglycemia does not increase correspondingly. This aligns with the results of previous reviews [15,16,18,113-115]. In recent years, there has been an increasing focus on long-term outcomes in diabetes care [116-122]. The long-term outcomes of implementing CDSSs are still unknown; thus, further research with long-term outcomes is needed.

An evident disparity was observed between the care recommended by clinical guidelines and the actual care provided to patients, ultimately leading to suboptimal glycemic control outcomes [123]. CDSSs might play a vital role in improving the quality of diabetes care in the following ways:

- CDSSs were most commonly used to provide recommendations for insulin dose adjustment (30/81, 37%).

For insulin users, it is critical to adjust the insulin dose properly and frequently according to patients' blood glucose levels, physical activity, and dietary patterns, which requires patients to undergo frequent clinical visits and HCPs with clinical experience and expertise [103]. HCPs with limited clinical experience might find insulin dose adjustment to be a challenge. CDSSs leverage data (eg, glucose level, insulin delivery rate, and food intake) from patient devices to automatically generate precise insulin dosing recommendations. The recommendations provided by CDSSs closely resemble those provided by experienced physicians, and a high rate of agreement with these recommendations is observed among HCPs [80,103,104].

- The secondary application of CDSSs is to provide drug recommendations (27/81, 33%). Managing diabetes has become increasingly complex with the expansion of treatment options and the growing emphasis on personalized care strategies outlined in the guidelines [124]. This presents a challenge for HCPs, particularly primary care physicians, who must balance managing multiple chronic conditions within limited time constraints [125]. By integrating the latest clinical guidelines with patients' clinical characteristics, CDSSs provide HCPs with advice on drug selection, improving their decision-making efficiency in developing individualized treatment plans.

- CDSSs have been shown to improve users' adherence (eg, adherence to medication suggestions, care guidelines, and follow-up appointments), which might improve clinical inertia. Clinical inertia, defined as "the failure to initiate or intensify therapy in a timely manner according to evidence-based clinical guidelines in individuals who are likely to benefit from such intensification" [126], is common in diabetes care and is caused by multifaceted factors [126,127]. CDSSs for patients with diabetes provide blood glucose monitoring and medical education, which could strengthen patients' awareness of their chronic conditions and increase patients' willingness for treatment modification. CDSSs for HCPs offer valuable support via treatment recommendations and physician training, thereby enhancing the ability of HCPs to make optimal decisions based on the unique needs of each patient, facilitating them in promptly and effectively modifying treatment regimens.

CDSSs Might Be More Required in Some Specific Contexts

CDSSs might be most useful for HCPs with limited formal education and practical experience in diabetes care or for patients with limited access to medical resources [84,128]. As the incidence of diabetes continues to rise and the number of qualified endocrinologists remains inadequate [11], primary care physicians might find themselves increasingly responsible for managing patients with diabetes [84,129]. Primary care physicians face challenges in diabetes management as they usually deal with multiple health issues and have little experience with the standard of care for diabetes [130]. Our review revealed that primary care physicians are the main users of CDSSs in diabetes care, especially in the scenario of drug recommendations, likely due to their lack of knowledge of the latest guidelines compared to specialized endocrinologists.

Regarding glucose management, nonphysician HCPs (eg, nurses, medical assistants, and pharmacists) and nonendocrinologists face comparable situations to those of primary care physicians, suggesting that CDSSs have great potential for application in these situations. Our review found that some nurses, medical assistants, pharmacists, and nonendocrinologists have initiated the use of CDSSs in diabetes care.

Additionally, effective diabetes care is a multifaceted process that relies not only on the expertise of HCPs but also on the active participation of patients in managing their diet, exercise routine, medication management, and other important health factors [131]. Benefiting from the development of mobile internet technology, our review found an increasing trend of CDSSs being developed for patient-oriented care. These CDSSs could facilitate patient self-management in diverse application scenarios, such as providing recommendations for insulin dose adjustment, providing suggestions for diet and exercise, providing medical education, and monitoring blood glucose. This might be especially appealing to patients who live in rural areas or have limited access to in-person physician visits [84].

Challenges and Prospects of CDSSs in Diabetes Care

Sirajuddin' et al [132] stated that for modern CDSSs to be effective, they should follow the Five Rights model. This model emphasizes that delivering "the right information to the right person, in the right format, through the right channel, and at the right time" is crucial for achieving lasting improvements. This ScR found that not all CDSSs could fit the model.

One of the challenges identified in this study was the suboptimal format and channel, such as the lack of integration with hospital electronic systems and the unfavorable design of the CDSS's human-computer interaction [23]. Integration of CDSSs into hospital systems to reduce physicians' workload [133], expediting software iteration, and developing CDSSs in collaboration with physicians [134] could help resolve these challenges.

Some CDSSs in the studies included reported challenges in providing the "right information." User acceptability of CDSS recommendations has decreased due to incomplete data collection [23] and delayed updates to the CDSS knowledge base [72]. Smart wearable devices could be leveraged to improve the efficiency and accuracy of data collection [135] and assist in making specific recommendations as opposed to a variety of suggestions. It is challenging to timely manage and maintain the rules (created based on expert knowledge, guidelines, etc) of CDSSs. Outdated rules could lead to inaccurate suggestions for treatments or preventive services. The extensive range of available data sets has led to the application of new methods (eg, association rule mining and machine learning algorithms) to explore novel modes of knowledge, which might reduce the cost of updating and maintaining the knowledge base [128].

In addition, our review found that although knowledge-based CDSSs remain the most commonly used type, the rise of AI and big data has led to an increase in non-knowledge-based CDSSs, which are primarily used to provide treatment recommendations for insulin dose adjustment and predict the patient's risk of complications. It is possible that we are currently undergoing a transformation from the rule-based approach to new methods, such as machine learning combined with voluminous clinical databases, offering more precise and personalized approaches to health care [128,136].

Furthermore, CDSSs might be effective and safe in improving diabetes care, but the cost of design, local implementation, ongoing maintenance, and user support for CDSSs could be high [137,138], which might be a significant barrier to fully implementing CDSSs. In the view of service payers (eg, health care facilities, insurers, and policy makers) promoting the use of CDSSs, it is important to find evidence about whether CDSSs are cost-effective in improving diabetes care. However, few studies have reported the cost and economic benefits of CDSS implementation.

Implications for Future Research

As discussed before, there are several research gaps. Future research should:

- Consider long-term follow-up to expand the range of outcomes, such as major adverse cardiovascular events (MACE), heart failure, and chronic kidney disease
- Investigate the use of CDSSs by nonphysician HCPs (eg, nurses, medical assistants, and pharmacists) and health care physicians not specialized in diabetes care
- Explore the implementation of CDSSs in diabetes care in cases of limited resources
- Evaluate the cost-effectiveness of CDSSs in diabetes care

Limitations

This ScR has several limitations. First, publication bias could exist in the studies included as negative results may not always be published. Second, this ScR could be subject to information bias due to certain data being collected based on subjective judgment. However, senior researchers and experts participated in data validation and verification to minimize potential bias. For instance, it is difficult to distinguish between knowledge-based and non-knowledge-based CDSSs. To address this issue, we enlisted the assistance of industry professionals to identify the decision-making mechanisms of CDSSs, but misclassification might still exist. Lastly, the great heterogeneity in CDSSs' design, purpose, and targets for evaluation prevented us from conducting a quality assessment and a meta-analysis, which according to ScR guidelines is usually not required.

Conclusion

This ScR found that CDSSs are being increasingly used in diabetes care and have been widely implemented by diverse users across various scenarios. They have been shown to be effective and safe in improving diabetes care, implying that CDSSs can be a reliable assistant for physicians and might be particularly helpful for physicians with limited experience and patients with limited access to medical resources. CDSSs also face some challenges and necessitate ongoing optimization iterations. Future studies should focus on further improving CDSS performance, evaluating their long-term effects and cost-effectiveness, and promoting their usage among HCPs and patients beyond endocrinology.

Acknowledgments

Authors' Contributions

SH, YL, JL, and XL designed the study; XL and YL collected the studies; SH and JL conducted data extraction; XL and YL performed the analysis; SH and JL critically commented on analysis results; and SH, YL, JL, and XL wrote the manuscript.

Conflicts of Interest

None declared.

Multimedia Appendix 1

Search strategy.
[[DOC File , 52 KB-Multimedia Appendix 1]](#)

Multimedia Appendix 2

PRISMA-ScR checklist.
[[DOCX File , 86 KB-Multimedia Appendix 2]](#)

Multimedia Appendix 3

Number of publications and subjects over time (N=85).
[[DOC File , 80 KB-Multimedia Appendix 3]](#)

Multimedia Appendix 4

Summary of users' adherence.
[[DOC File , 59 KB-Multimedia Appendix 4]](#)

References

1. Sun H, Saeedi P, Karuranga S, Pinkepank M, Ogurtsova K, Duncan BB, et al. IDF Diabetes Atlas: global, regional and country-level diabetes prevalence estimates for 2021 and projections for 2045. Diabetes Res Clin Pract. 2022 Jan;183:109119 [doi: 10.1016/j.diabres.2021.109119] [Medline: 34879977]

2. Magliano D, Boyko E, IDF Diabetes Atlas 10th Edition Scientific Committee. IDF Diabetes Atlas 10th Edition. Brussels. International Diabetes Federation; 2021.

3. Okemah J, Peng J, Quiñones M. Addressing clinical inertia in type 2 diabetes mellitus: a review. Adv Ther. 2018 Nov 29;35(11):1735-1745 [FREE Full text] [doi: 10.1007/s12325-018-0819-5] [Medline: 30374807]

4. Khunti K, Giorgino F, Berard L, Mauricio D, Harris SB. The importance of the initial period of basal insulin titration in people with diabetes. Diabetes Obes Metab. 2020 May 19;22(5):722-733 [FREE Full text] [doi: 10.1111/dom.13946] [Medline: 31865632]

5. Paul SK, Klein K, Thorsted BL, Wolden ML, Khunti K. Delay in treatment intensification increases the risks of cardiovascular events in patients with type 2 diabetes. Cardiovasc Diabetol. 2015 Aug 07;14:100 [FREE Full text] [doi: 10.1186/s12933-015-0260-x] [Medline: 26249018]

6. Blonde L, Aschner P, Bailey C, Ji L, Leiter LA, Matthaei S, et al. Global Partnership for Effective Diabetes Management. Gaps and barriers in the control of blood glucose in people with type 2 diabetes. Diabetes Vasc Dis Res. 2017 May 01;14(3):172-183 [FREE Full text] [doi: 10.1177/1479164116679775] [Medline: 28467203]

7. Goodall G, Sarpong EM, Hayes C, Valentine WJ. The consequences of delaying insulin initiation in UK type 2 diabetes patients failing oral hyperglycaemic agents: a modelling study. BMC Endocr Disord. 2009 Oct 05;9(1):19 [FREE Full text] [doi: 10.1186/1472-6823-9-19] [Medline: 19804622]

8. Bain SC, Feher M, Russell-Jones D, Khunti K. Management of type 2 diabetes: the current situation and key opportunities to improve care in the UK. Diabetes Obes Metab. 2016 Dec 14;18(12):1157-1166 [doi: 10.1111/dom.12760] [Medline: 27491724]

9. Nathan D, DCCT/EDIC Research Group. The diabetes control and complications trial/epidemiology of diabetes interventions and complications study at 30 years: overview. Diabetes Care. 2014;37(1):9-16 [FREE Full text] [doi: 10.2337/dc13-2112] [Medline: 24356592]

10. Zoungas S. ADVANCE in context: the benefits, risks and feasibility of providing intensive glycaemic control based on gliclazide modified release. Diabetes Obes Metab. 2020 Apr 06;22(Suppl 2):5-11 [doi: 10.1111/dom.13968] [Medline: 32250522]

11. Vigersky RA, Fish L, Hogan P, Stewart A, Kutler S, Ladenson PW, et al. The clinical endocrinology workforce: current status and future projections of supply and demand. J Clin Endocrinol Metab. 2014 Sep;99(9):3112-3121 [doi: 10.1210/jc.2014-2257] [Medline: 24940655]

12. Sutton RT, Pincock D, Baumgart DC, Sadowski DC, Fedorak RN, Kroeker KI. An overview of clinical decision support systems: benefits, risks, and strategies for success. NPJ Digit Med. 2020;3:17 [FREE Full text] [doi: 10.1038/s41746-020-0221-y] [Medline: 32047862]

13. Ackermann K, Baker J, Green M, Fullick M, Varinli H, Westbrook J, et al. Computerized clinical decision support systems for the early detection of sepsis among adult inpatients: scoping review. J Med Internet Res. 2022 Feb 23;24(2):e31083 [FREE Full text] [doi: 10.2196/31083] [Medline: 35195528]

14. Berner E. Clinical Decision Support Systems. New York. Springer; 2007.

15. Jia P, Jia P, Chen J, Zhao P, Zhang M. The effects of clinical decision support systems on insulin use: a systematic review. J Eval Clin Pract. 2020 Aug;26(4):1292-1301 [doi: 10.1111/jep.13291] [Medline: 31782586]

16. Ali SM, Giordano R, Lakhani S, Walker DM. A review of randomized controlled trials of medical record powered clinical decision support system to improve quality of diabetes care. Int J Med Inform. 2016 Mar;87:91-100 [doi: 10.1016/j.ijmedinf.2015.12.017] [Medline: 26806716]

17. Nirantharakumar K, Chen YF, Marshall T, Webber J, Coleman JJ. Clinical decision support systems in the care of inpatients with diabetes in non-critical care setting: systematic review. Diabetes Med. 2012 Jun 16;29(6):698-708 [doi: 10.1111/j.1464-5491.2011.03540.x] [Medline: 22150466]

18. Sly B, Russell AW, Sullivan C. Digital interventions to improve safety and quality of inpatient diabetes management: a systematic review. Int J Med Inform. 2022 Jan;157:104596 [doi: 10.1016/j.ijmedinf.2021.104596] [Medline: 34785487]

19. Vettoretti M, Cappon G, Facchinetti A, Sparacino G. Advanced diabetes management using artificial intelligence and continuous glucose monitoring sensors. Sensors (Basel). 2020 Jul 10;20(14):3870-3887 [FREE Full text] [doi: 10.3390/s20143870] [Medline: 32664432]

20. Tyler NS, Jacobs PG. Artificial intelligence in decision support systems for type 1 diabetes. Sensors (Basel). 2020 Jun 05;20(11):3214 [FREE Full text] [doi: 10.3390/s20113214] [Medline: 32517068]

21. Woldaregay AZ, Årsand E, Botsis T, Albers D, Mamykina L, Hartvigsen G. Data-driven blood glucose pattern classification and anomalies detection: machine-learning applications in type 1 diabetes. J Med Internet Res. 2019 May 01;21(5):e11030 [FREE Full text] [doi: 10.2196/11030] [Medline: 31042157]

22. Cleveringa FG, Gorter KJ, van den Donk M, van Gijsel J, Rutten GE. Computerized decision support systems in primary care for type 2 diabetes patients only improve patients' outcomes when combined with feedback on performance and case management: a systematic review. Diabetes Technol Ther. 2013 Feb;15(2):180-192 [doi: 10.1089/dia.2012.0201] [Medline: 23360424]

23. Zhang X, Svec M, Tracy R, Ozanich G. Clinical decision support systems with team-based care on type 2 diabetes improvement for Medicaid patients: a quality improvement project. Int J Med Inform. 2021 Nov 18;158:104626 [doi: 10.1016/j.ijmedinf.2021.104626] [Medline: 34826757]

24. Pal K, Eastwood SV, Michie S, Farmer A, Barnard ML, Peacock R, et al. Computer-based interventions to improve self-management in adults with type 2 diabetes: a systematic review and meta-analysis. Diabetes Care. 2014 Jun 22;37(6):1759-1766 [FREE Full text] [doi: 10.2337/dc13-1386] [Medline: 24855158]

25. Neher M, Nygårdh A, Nilsen P, Broström A, Johansson P. Implementing internet-delivered cognitive behavioural therapy for patients with cardiovascular disease and psychological distress: a scoping review. Eur J Cardiovasc Nurs. 2019 Jun 22;18(5):346-357 [doi: 10.1177/1474515119833251] [Medline: 30795698]

26. Tran DM, Thwaites CL, Van Nuil JI, McKnight J, Luu AP, Paton C, et al. Vietnam ICU Translational Applications Laboratory (VITAL). Digital health policy and programs for hospital care in Vietnam: scoping review. J Med Internet Res. 2022 Feb 09;24(2):e32392 [FREE Full text] [doi: 10.2196/32392] [Medline: 35138264]

27. Arksey H, O'Malley L. Scoping studies: towards a methodological framework. Int J Soc Res Methodol. 2005 Feb;8(1):19-32 [doi: 10.1080/1364557032000119616]

28. Peterson CM, Jovanovic L, Chanoch LH. Randomized trial of computer-assisted insulin delivery in patients with type I diabetes beginning pump therapy. Am J Med. 1986 Jul;81(1):69-72 [doi: 10.1016/0002-9343(86)90184-1] [Medline: 3524226]

29. Buysschaert M, Jacques D, Donckier J, Lambert A. Effect of computer-assisted insulin delivery on glycemic control of type I diabetic patients: a preliminary experience. Acta Clin Belg. 1989 May 16;44(3):169-173 [doi: 10.1080/17843286.1989.11718009] [Medline: 2683537]

30. Peters A, Rübsamen M, Jacob U, Look D, Scriba P. Clinical evaluation of decision support system for insulin-dose adjustment in IDDM. Diabetes Care. 1991 Oct;14(10):875-880 [doi: 10.2337/diacare.14.10.875] [Medline: 1773685]

31. Nilasena DS, Lincoln MJ, Turner CW, Warner HR, Foerster VA, Williamson JW, et al. Development and implementation of a computer-generated reminder system for diabetes preventive care. Proc Annu Symp Comput Appl Med Care. 1994:831-835 [FREE Full text] [Medline: 7950041]

32. Holman RR, Smale AD, Pemberton E, Riefflin A, Nealon JL. Randomized controlled pilot trial of a hand-held patient-oriented, insulin regimen optimizer. Med Inform (Lond). 1996 Jul 12;21(4):317-326 [doi: 10.3109/14639239608999292] [Medline: 9179835]

33. Lobach DF, Hammond W. Computerized decision support based on a clinical practice guideline improves compliance with care standards. Am J Med. 1997 Jan;102(1):89-98 [doi: 10.1016/s0002-9343(96)00382-8] [Medline: 9209205]

34. Strowig S, Raskin P. Improved glycemic control in intensively treated type 1 diabetic patients using blood glucose meters with storage capability and computer-assisted analyses. Diabetes Care. 1998 Oct;21(10):1694-1698 [doi: 10.2337/diacare.21.10.1694] [Medline: 9773733]

35. Hetlevik I, Holmen J, Krüger O, Kristensen P, Iversen H, Furuseth K. Implementing clinical guidelines in the treatment of diabetes mellitus in general practice. Evaluation of effort, process, and patient outcome related to implementation of a computer-based decision support system. Int J Technol Assess Health Care. 2000 May 04;16(1):210-227 [doi: 10.1017/s0266462300161185] [Medline: 10815366]

36. Schrezenmeir J, Dirting K, Papazov P. Controlled multicenter study on the effect of computer assistance in intensive insulin therapy of type 1 diabetics. Comput Methods Programs Biomed. 2002 Aug;69(2):97-114 [doi: 10.1016/s0169-2607(02)00034-2] [Medline: 12100790]

37. Cavan DA, Everett J, Plougmann S, Hejlesen OK. Use of the internet to optimize self-management of type 1 diabetes: preliminary experience with DiasNet. J Telemed Telecare. 2003 Dec 02;9(Suppl 1):S50-S52 [doi: 10.1258/135763303322196330] [Medline: 12952722]

38. Meigs J, Cagliero E, Dubey A, Murphy-Sheehy P, Gildesgame C, Chueh H, et al. A controlled trial of web-based diabetes disease management: the MGH diabetes primary care improvement project. Diabetes Care. 2003 Mar;26(3):750-757 [doi: 10.2337/diacare.26.3.750] [Medline: 12610033]

39. Zhou YD, Gu W. [Computer assisted nutrition therapy for patients with type 2 diabetes]. J ZheJiang Univ (Med Sci). 2003 Jun;32(3):244-248 [doi: 10.3785/j.issn.1008-9292.2003.03.019] [Medline: 12881874]

40. Kwon H, Cho J, Kim H, Song B, Ko S, Lee J, et al. Establishment of blood glucose monitoring system using the internet. Diabetes Care. 2004 Feb 27;27(2):478-483 [doi: 10.2337/diacare.27.2.478] [Medline: 14747232]

41. Glasgow R, Nutting P, King D, Nelson CC, Cutter G, Gaglio B, et al. Randomized effectiveness trial of a computer-assisted intervention to improve diabetes care. Diabetes Care. 2005 Jan;28(1):33-39 [doi: 10.2337/diacare.28.1.33] [Medline: 15616230]

42. McMahon G, Gomes H, Hickson Hohne S, Hu T, Levine B, Conlin P. Web-based care management in patients with poorly controlled diabetes. Diabetes Care. 2005 Jul;28(7):1624-1629 [FREE Full text] [doi: 10.2337/diacare.28.7.1624] [Medline: 15983311]

43. Augstein P, Vogt L, Kohnert K, Freyse E, Heinke P, Salzsieder E. Outpatient assessment of Karlsburg Diabetes Management System-based decision support. Diabetes Care. 2007 Jul;30(7):1704-1708 [doi: 10.2337/dc06-2167] [Medline: 17468357]

44. Cleveringa FG, Gorter KJ, van den Donk M, Pijman PL, Rutten GE. Task delegation and computerized decision support reduce coronary heart disease risk factors in type 2 diabetes patients in primary care. Diabetes Technol Ther. 2007 Oct;9(5):473-481 [doi: 10.1089/dia.2007.0210] [Medline: 17931055]

45. Holbrook A, Thabane L, Keshavjee K, Dolovich L, Bernstein B, Chan D, et al. COMPETE II Investigators. Individualized electronic decision support and reminders to improve diabetes care in the community: COMPETE II randomized trial. Can Med Assoc J. 2009 Jul 07;181(1-2):37-44 [FREE Full text] [doi: 10.1503/cmaj.081272] [Medline: 19581618]

46. Augstein P, Vogt L, Kohnert K, Heinke P, Salzsieder E. Translation of personalized decision support into routine diabetes care. J Diabetes Sci Technol. 2010 Nov 01;4(6):1532-1539 [FREE Full text] [doi: 10.1177/193229681000400631] [Medline: 21129352]

47. Cleveringa FGW, Welsing PMJ, van den Donk M, Gorter KJ, Niessen LW, Rutten GEHM, et al. Cost-effectiveness of the diabetes care protocol, a multifaceted computerized decision support diabetes management intervention that reduces cardiovascular risk. Diabetes Care. 2010 Feb;33(2):258-263 [FREE Full text] [doi: 10.2337/dc09-1232] [Medline: 19933991]

48. Barletta JF, McAllen KJ, Eriksson EA, Deines G, Blau SA, Thayer SC, et al. The effect of a computer-assisted insulin protocol on glycemic control in a surgical intensive care unit. Diabetes Technol Ther. 2011 Apr;13(4):495-500 [doi: 10.1089/dia.2010.0227] [Medline: 21355721]

49. Lim S, Kang SM, Shin H, Lee HJ, Won Yoon J, Yu SH, et al. Improved glycemic control without hypoglycemia in elderly diabetic patients using the ubiquitous healthcare service, a new medical information system. Diabetes Care. 2011 Feb;34(2):308-313 [FREE Full text] [doi: 10.2337/dc10-1447] [Medline: 21270188]

50. O'Connor PJ, Sperl-Hillen JM, Rush WA, Johnson PE, Amundson GH, Asche SE, et al. Impact of electronic health record clinical decision support on diabetes care: a randomized trial. Ann Fam Med. 2011 Jan 17;9(1):12-21 [FREE Full text] [doi: 10.1370/afm.1196] [Medline: 21242556]

51. Quinn CC, Shardell MD, Terrin ML, Barr EA, Ballew SH, Gruber-Baldini AL. Cluster-randomized trial of a mobile phone personalized behavioral intervention for blood glucose control. Diabetes Care. 2011 Sep 25;34(9):1934-1942 [FREE Full text] [doi: 10.2337/dc11-0366] [Medline: 21788632]

52. Rodbard H, Schnell O, Unger J, Rees C, Amstutz L, Parkin CG, et al. Use of an automated decision support tool optimizes clinicians' ability to interpret and appropriately respond to structured self-monitoring of blood glucose data. Diabetes Care. 2012 Apr;35(4):693-698 [FREE Full text] [doi: 10.2337/dc11-1351] [Medline: 22344611]

53. Sáenz A, Brito M, Morón I, Torralba A, García-Sanz E, Redondo J. Development and validation of a computer application to aid the physician's decision-making process at the start of and during treatment with insulin in type 2 diabetes: a randomized and controlled trial. J Diabetes Sci Technol. 2012 May 01;6(3):581-588 [FREE Full text] [doi: 10.1177/193229681200600313] [Medline: 22768889]

54. Gunathilake W, Gunawardena S, Fernando R, Thomson G, Fernando D. The impact of a decision support tool linked to an electronic medical record on glycemic control in people with type 2 diabetes. J Diabetes Sci Technol. 2013 May 01;7(3):653-659 [FREE Full text] [doi: 10.1177/193229681300700310] [Medline: 23759398]

55. Oxendine V, Meyer A, Reid P, Adams A, Sabol V. Evaluating Diabetes Outcomes and Costs Within an Ambulatory Setting: A Strategic Approach Utilizing a Clinical Decision Support System. Clin Diabetes. 2014 Jul;32(3):113-120 [FREE Full text] [doi: 10.2337/diaclin.32.3.113] [Medline: 26246682]

56. Tokunaga-Nakawatase Y, Nishigaki M, Taru C, Miyawaki I, Nishida J, Kosaka S, et al. Computer-supported indirect-form lifestyle-modification support program using Lifestyle Intervention Support Software for Diabetes Prevention (LISS-DP) for people with a family history of type 2 diabetes in a medical checkup setting: a randomized controlled trial. Prim Care Diabetes. 2014 Oct;8(3):207-214 [doi: 10.1016/j.pcd.2014.01.007] [Medline: 24529485]

57. Neubauer KM, Mader JK, Höll B, Aberer F, Donsa K, Augustin T, et al. Standardized glycemic management with a computerized workflow and decision support system for hospitalized patients with type 2 diabetes on different wards. Diabetes Technol Ther. 2015 Oct;17(10):685-692 [FREE Full text] [doi: 10.1089/dia.2015.0027] [Medline: 26355756]

58. Ajay VS, Jindal D, Roy A, Venugopal V, Sharma R, Pawar A, et al. Development of a smartphone‐enabled hypertension and diabetes mellitus management package to facilitate evidence‐based care delivery in primary healthcare facilities in India: the mPower heart project. J Am Heart Assoc. 2016 Dec 19;5(12):e004343-e004352 [doi: 10.1161/jaha.116.004343]

59. Bailey RA, Pfeifer M, Shillington AC, Harshaw Q, Funnell MM, VanWingen J, et al. Effect of a patient decision aid (PDA) for type 2 diabetes on knowledge, decisional self-efficacy, and decisional conflict. BMC Health Serv Res. 2016 Jan 14;16(1):10 [FREE Full text] [doi: 10.1186/s12913-016-1262-4] [Medline: 26762150]

60. Donsa K, Beck P, Höll B, Mader JK, Schaupp L, Plank J, et al. Impact of errors in paper-based and computerized diabetes management with decision support for hospitalized patients with type 2 diabetes. a post-hoc analysis of a before and after study. Int J Med Inform. 2016 Jun;90:58-67 [doi: 10.1016/j.ijmedinf.2016.03.007] [Medline: 27103198]

61. Lim S, Kang SM, Kim KM, Moon JH, Choi SH, Hwang H, et al. Multifactorial intervention in diabetes care using real-time monitoring and tailored feedback in type 2 diabetes. Acta Diabetol. 2016 Apr;53(2):189-198 [doi: 10.1007/s00592-015-0754-8] [Medline: 25936739]

62. Maia JX, de Sousa LAP, Marcolino MS, Cardoso CS, da Silva JLP, Alkmim MBM, et al. The impact of a clinical decision support system in diabetes primary care patients in a developing country. Diabetes Technol Ther. 2016 Apr;18(4):258-263 [doi: 10.1089/dia.2015.0253] [Medline: 26840128]

63. Or C, Tao D. A 3-month randomized controlled pilot trial of a patient-centered, computer-based self-monitoring system for the care of type 2 diabetes mellitus and hypertension. J Med Syst. 2016 Apr;40(4):81 [doi: 10.1007/s10916-016-0437-1] [Medline: 26802011]

64. Reddy M, Pesl P, Xenou M, Toumazou C, Johnston D, Georgiou P, et al. Clinical safety and feasibility of the advanced bolus calculator for type 1 diabetes based on case-based reasoning: a 6-week nonrandomized single-arm pilot study. Diabetes Technol Ther. 2016 Aug;18(8):487-493 [FREE Full text] [doi: 10.1089/dia.2015.0413] [Medline: 27196358]

65. Beltrán LM, Olmo-Fernández A, Banegas JR, García-Puig J. Electronic clinical decision support system and multifactorial risk factor control in patients with type 2 diabetes in primary health care. Eur J Intern Med. 2017 Oct;44:e35-e37 [doi: 10.1016/j.ejim.2017.07.024] [Medline: 28747256]

66. Hannon TS, Dugan TM, Saha CK, McKee SJ, Downs SM, Carroll AE. Effectiveness of computer automation for the diagnosis and management of childhood type 2 diabetes: a randomized clinical trial. JAMA Pediatr. 2017 Apr 01;171(4):327-334 [FREE Full text] [doi: 10.1001/jamapediatrics.2016.4207] [Medline: 28192551]

67. Spat S, Donsa K, Beck P, Höll B, Mader JK, Schaupp L, et al. A mobile computerized decision support system to prevent hypoglycemia in hospitalized patients with type 2 diabetes mellitus: lessons learned from a clinical feasibility study. J Diabetes Sci Technol. 2017 Jan 03;11(1):20-28 [FREE Full text] [doi: 10.1177/1932296816676501] [Medline: 27810995]

68. Bode B, Clarke JG, Johnson J. Use of decision support software to titrate multiple daily injections yielded sustained A1c reductions after 1 year. J Diabetes Sci Technol. 2018 Jan 17;12(1):124-128 [FREE Full text] [doi: 10.1177/1932296817747886] [Medline: 29251061]

69. Breton MD, Patek SD, Lv D, Schertz E, Robic J, Pinnata J, et al. Continuous glucose monitoring and insulin informed advisory system with automated titration and dosing of insulin reduces glucose variability in type 1 diabetes mellitus. Diabetes Technol Ther. 2018 Aug;20(8):531-540 [FREE Full text] [doi: 10.1089/dia.2018.0079] [Medline: 29979618]

70. Panattoni L, Chan A, Yang Y, Olson C, Tai-Seale M. Nudging physicians and patients with autopend clinical decision support to improve diabetes management. Am J Manag Care. 2018 Oct;24(10):479-483 [FREE Full text] [Medline: 30325190]

71. Pérez-Gandía C, García-Sáez G, Subías D, Rodríguez-Herrero A, Gómez EJ, Rigla M, et al. Decision support in diabetes care: the challenge of supporting patients in their daily living using a mobile glucose predictor. J Diabetes Sci Technol. 2018 Mar;12(2):243-250 [FREE Full text] [doi: 10.1177/1932296818761457] [Medline: 29493361]

72. Singh K, Johnson L, Devarajan R, Shivashankar R, Sharma P, Kondal D, et al. Acceptability of a decision-support electronic health record system and its impact on diabetes care goals in South Asia: a mixed-methods evaluation of the CARRS trial. Diabetes Med. 2018 Dec 19;35(12):1644-1654 [doi: 10.1111/dme.13804] [Medline: 30142228]

73. Aberer F, Lichtenegger KM, Smajic E, Donsa K, Malle O, Samonigg J, et al. GlucoTab-guided insulin therapy using insulin glargine U300 enables glycaemic control with low risk of hypoglycaemia in hospitalized patients with type 2 diabetes. Diabetes Obes Metab. 2019 Mar;21(3):584-591 [FREE Full text] [doi: 10.1111/dom.13559] [Medline: 30328252]

74. Gill J, Kucharski K, Turk B, Pan C, Wei W. Using electronic clinical decision support in patient-centered medical homes to improve management of diabetes in primary care: the DECIDE Study. J Ambulatory Care Manage. 2019;42(2):105-115 [doi: 10.1097/jac.0000000000000267]

75. Kim EK, Kwak SH, Jung HS, Koo BK, Moon MK, Lim S, et al. The effect of a smartphone-based, patient-centered diabetes care system in patients with type 2 diabetes: a randomized, controlled trial for 24 weeks. Diabetes Care. 2019 Jan 30;42(1):3-9 [doi: 10.2337/dc17-2197] [Medline: 30377185]

76. Luo Y, Zhu Y, Chen J, Gao X, Yang W, Zou X, et al. A decision-support software to improve the standard care in Chinese type 2 diabetes. J Diabetes Res. 2019 Nov 11;2019:5491743-5491746 [FREE Full text] [doi: 10.1155/2019/5491743] [Medline: 31828162]

77. Mader JK, Motschnig M, Theiler-Schwetz V, Eibel-Reisz K, Reisinger AC, Lackner B, et al. Feasibility of blood glucose management using intra-arterial glucose monitoring in combination with an automated insulin titration algorithm in critically Ill patients. Diabetes Technol Ther. 2019 Oct 01;21(10):581-588 [doi: 10.1089/dia.2019.0082] [Medline: 31335205]

78. Prabhakaran D, Jha D, Prieto-Merino D, Roy A, Singh K, Ajay VS, et al. Members of the Research Steering Committee, Investigators, Members of the Data SafetyMonitoring Board. Effectiveness of an mHealth-based electronic decision support system for integrated management of chronic conditions in primary care: the mWellcare cluster-randomized controlled trial. Circulation. 2019 Jan 15;139(3):380-391 [FREE Full text] [doi: 10.1161/CIRCULATIONAHA.118.038192] [Medline: 30586732]

79. Belli HM, Chokshi SK, Hegde R, Troxel AB, Blecker S, Testa PA, et al. Implementation of a behavioral economics electronic health record (BE-EHR) module to reduce overtreatment of diabetes in older adults. J Gen Intern Med. 2020 Nov 03;35(11):3254-3261 [FREE Full text] [doi: 10.1007/s11606-020-06119-z] [Medline: 32885374]

80. El Fathi A, Palisaitis E, von Oettingen JE, Krishnamoorthy P, Kearney RE, Legault L, et al. A pilot non-inferiority randomized controlled trial to assess automatic adjustments of insulin doses in adolescents with type 1 diabetes on multiple daily injections therapy. Pediatr Diabetes. 2020 Sep 11;21(6):950-959 [doi: 10.1111/pedi.13052] [Medline: 32418302]

81. Heselmans A, Delvaux N, Laenen A, Van de Velde S, Ramaekers D, Kunnamo I, et al. Computerized clinical decision support system for diabetes in primary care does not improve quality of care: a cluster-randomized controlled trial. Implement Sci. 2020 Jan 07;15(1):5 [FREE Full text] [doi: 10.1186/s13012-019-0955-6] [Medline: 31910877]

82. Hochfellner D, Rainer R, Aberer F. Effective and safe basal-bolus insulin therapy during fasting episodes in hospitalised patients with type 2 diabetes using decision support technology. Diabetologia. 2020;63(SUPPL 1):S377-S378 [doi: 10.1111/dom.14458/v1/review1]

83. Murphy ME, McSharry J, Byrne M, Boland F, Corrigan D, Gillespie P, et al. Supporting care for suboptimally controlled type 2 diabetes mellitus in general practice with a clinical decision support system: a mixed methods pilot cluster randomised trial. BMJ Open. 2020 Feb 12;10(2):e032594 [FREE Full text] [doi: 10.1136/bmjopen-2019-032594] [Medline: 32051304]

84. Nimri R, Battelino T, Laffel LM, Slover RH, Schatz D, Weinzimer SA, et al. NextDREAM Consortium. Insulin dose optimization using an automated artificial intelligence-based decision support system in youths with type 1 diabetes. Nat Med. 2020 Sep;26(9):1380-1384 [doi: 10.1038/s41591-020-1045-7] [Medline: 32908282]

85. Weiner M, Cummins J, Raji A, Ofner S, Iglay K, Teal E, et al. A randomized study on the usefulness of an electronic outpatient hypoglycemia risk calculator for clinicians of patients with diabetes in a safety-net institution. Curr Med Res Opin. 2020 Apr 06;36(4):583-593 [doi: 10.1080/03007995.2020.1717451] [Medline: 31951747]

86. Aleppo G, DeSalvo D, Lauand F. Glycaemic improvement in 3,436 people with type 1 diabetes using the omnipod DASH® insulin management system over first 90 days of use. Diabetologia. 2021;64(SUPPL 1):S112-S112 [doi: 10.2337/db21-698-p]

87. Augstein P, Heinke P, Vogt L, Kohnert K, Salzsieder E. Patient-tailored decision support system improves short- and long-term glycemic control in type 2 diabetes. J Diabetes Sci Technol. 2022 Sep 18;16(5):1159-1166 [FREE Full text] [doi: 10.1177/19322968211008871] [Medline: 34000840]

88. Avari P, Leal Y, Herrero P, Wos M, Jugnee N, Arnoriaga-Rodríguez M, et al. Safety and feasibility of the PEPPER adaptive bolus advisor and safety system: a randomized control study. Diabetes Technol Ther. 2021 Mar 01;23(3):175-186 [doi: 10.1089/dia.2020.0301] [Medline: 33048581]

89. Desai J, Crain A, Saman D. 859-P: impact of a prediabetes clinical decision support system on CV risk factor control in primary care: randomized trial. Diabetes. 2021 Jun 1;70(Supplement_1):859-P [doi: 10.2337/db21-859-p]

90. Hochfellner D, Rainer R, Ziko H. Efficient and safe glycaemic control with basal-bolus insulin therapy during fasting periods in hospitalised patients with type 2 diabetes using decision support technology: a post-hoc analysis. Diabetes Obes Metab. 2021;23(9):2161-2169 [doi: 10.1111/dom.14458/v1/review1]

91. Kesavadev J, Saboo B, Shankar A. Impact of webinars and telemedicine during COVID-19 lockdown in transforming outcomes in 848 T2D patients in India. Diabetes. 2021 Jun 1;70(Supplement_1):468-P [doi: 10.2337/db21-468-p]

92. ATTD 2021. Invited speaker abstracts. Diabetes Technol Ther. 2021 Jun;23(S2):A1-A206 [doi: 10.1089/dia.2021.2525.abstracts] [Medline: 34061632]

93. Kumar D, Joshi A, Grover A, Raina S, Bhardwaj A, Malhotra B, et al. Effect of personalized human-centered dietary decision support system (PHCDDSS) on dietary knowledge, attitude, practice (KAP), and mean fasting blood sugar (FBS) among participants with type 2 diabetes mellitus (T2DM) in community-based settings of northern state of India. J Diabetol. 2021;12(3):338 [doi: 10.4103/jod.jod_21_21]

94. Lichtenegger KM, Aberer F, Tuca AC, Donsa K, Höll B, Schaupp L, et al. Safe and sufficient glycemic control by using a digital clinical decision support system for patients with type 2 diabetes in a routine setting on general hospital wards. J Diabetes Sci Technol. 2021 Mar 11;15(2):231-235 [FREE Full text] [doi: 10.1177/1932296820955243] [Medline: 32914640]

95. Muthuvel G, Brady P, Daraiseh N, Khoury J, Smith E, Tellez S, et al. Using artificial intelligence decision support to enhance care for type 1 diabetes. Pediatr Diabetes. 2021 Nov 10;22(S30):33-165 [doi: 10.1111/pedi.13269]

96. Pichardo-Lowden A, Umpierrez G, Lehman EB, Bolton MD, DeFlitch CJ, Chinchilli VM, et al. Clinical decision support to improve management of diabetes and dysglycemia in the hospital: a path to optimizing practice and outcomes. BMJ Open Diabetes Res Care. 2021 Jan 18;9(1):e001557 [FREE Full text] [doi: 10.1136/bmjdrc-2020-001557] [Medline: 33462075]

97. Ullal J, Dignan C, Cwik R, McFarland R, Gaines M, Aloi JA. Utility of computer-guided decision support system in discharge insulin dosing and diabetes-related readmissions. J Diabetes Sci Technol. 2021 Mar 19;15(2):523-524 [FREE Full text] [doi: 10.1177/1932296820949282] [Medline: 32814453]

98. Bisio A, Anderson S, Norlander L. Impact of a novel diabetes support system on a cohort of individuals with type 1 diabetes treated with multiple daily injections: a multicenter randomized study. Diabetes Care. 2022;45(1):186-193 [doi: 10.2337/dc21-0838]

99. Castle J, Espinoza A, Tyler N. 771-P: acceptance of decision support recommendations improves time in range for people living with type 1 diabetes on multiple daily injections. Diabetes. 2022 Jun;71(Supplement_1):771-P [doi: 10.2337/db22-771-p]

100. Derevyanko O, Rumyantseva T, Balashov A, Fomin D. Electronic health record with decision support as a tool to improve quality of care for women with postmenopausal osteoporosis. 2023 Presented at: 25th European Congress of Endocrinology; May 13-16, 2023; Istanbul, Turkey [doi: 10.1530/endoabs.90.ep175]

101. Ding Y, Yue T, Wu W. [Analysis of glucose changes in adults with type 1 diabetes mellitus within 1 year after using mobile APP decision support system]. Zhonghua Yi Xue Za Zhi. 2022 Apr 26;102(16):1196-1201 [doi: 10.3760/cma.j.cn112137-20211010-02240]

102. Hochfellner D, Baumann P, Beck P, Mader J. Algorithm-driven basal-bolus therapy in hospitalized patients with type 2 diabetes: implications for discharge therapy. Diabetes Technol Ther. 2022;24(Suppl 1):A28-A29

103. Nimri R, Oron T, Muller I, Kraljevic I, Alonso MM, Keskinen P, et al. Adjustment of insulin pump settings in type 1 diabetes management: advisor pro device compared to physicians' recommendations. J Diabetes Sci Technol. 2020 Oct 26;16(2):364-372 [doi: 10.1177/1932296820965561]

104. Nimri R, Tirosh A, Muller I, Shtrit Y, Phillip M. 89-OR: effective real-world usage of artificial intelligence?based decision support system for diabetes management. Diabetes 2022. 2022 Jun;71(Supplement_1):89-OR [doi: 10.2337/db22-89-or]

105. Pei X, Yao X, Yang Y, Zhang H, Xia M, Huang R, et al. Efficacy of artificial intelligence-based screening for diabetic retinopathy in type 2 diabetes mellitus patients. Diabetes Res Clin Pract. 2022 Feb;184:109190 [doi: 10.1016/j.diabres.2022.109190]

106. Pratt R, Saman DM, Allen C, Crabtree B, Ohnsorg K, Sperl-Hillen JM, et al. Assessing the implementation of a clinical decision support tool in primary care for diabetes prevention: a qualitative interview study using the Consolidated Framework for Implementation Science. BMC Med Inform Decis Mak. 2022 Jan 15;22(1):15 [doi: 10.1186/s12911-021-01745-x]

107. Romero-Aroca P, Verges R, Maarof N, Vallas-Mateu A, Latorre A, Moreno-Ribas A, et al. Real-world outcomes of a clinical decision support system for diabetic retinopathy in Spain. BMJ Open Ophth. 2022 Mar 28;7(1):e000974-e000980 [doi: 10.1136/bmjophth-2022-000974]

108. Ware P, Shah A, Ross HJ, Logan AG, Segal P, Cafazzo JA, et al. Challenges of telemonitoring programs for complex chronic conditions: randomized controlled trial with an embedded qualitative study. J Med Internet Res. 2022 Jan 26;24(1):e31754 [FREE Full text] [doi: 10.2196/31754] [Medline: 35080502]

109. Wilson L, Jacobs P, Guillot F. 291-OR: using the performance in exercise and knowledge (PEAK) guidelines incorporated in a smartphone-based decision support system improves glucose outcomes during free-living exercise. Diabetes. 2022 Jun;71(Supplement_1):291-OR [doi: 10.2337/db22-291-or]

110. Young G, Tyler N, Hilts W. Decision support system improves glucose control during and after aerobic exercise for users on multiple daily injection and closed-loop therapy, in silico. Diabetes Technol Ther. 2022;24(Suppl 1):A224-A225 [doi: 10.1530/endoabs.90.ep175]

111. Nascimento do Ó DMN, Rodrigues C, Sequeira M, Pires M, Cravinho R, Andrade R, et al. IDF2022-0470 health literacy in diabetes at pandemic time–remote educational and motivational program for type 2 diabetes patients. Diabetes Res Clin Pract. 2023 Mar;197:110419 [doi: 10.1016/j.diabres.2023.110419]

112. Osheroff J, Pifer E, Sittig D, Jenders R, Teich J. Clinical Decision Support Implementers' Workbook. Chicago, IL. HIMSS; 2004.

113. Nuti L, Turkcan A, Lawley MA, Zhang L, Sands L, McComb S. The impact of interventions on appointment and clinical outcomes for individuals with diabetes: a systematic review. BMC Health Serv Res. 2015 Sep 2;15(1):355 [FREE Full text] [doi: 10.1186/s12913-015-0938-5] [Medline: 26330299]

114. Ullal J, Aloi JA. Subcutaneous insulin dosing calculators for inpatient glucose control. Curr Diabetes Rep. 2019 Nov 04;19(11):120-127 [doi: 10.1007/s11892-019-1254-y]

115. Alharbi NS, Alsubki N, Jones S, Khunti K, Munro N, de LS. Impact of information technology-based interventions for type 2 diabetes mellitus on glycemic control: a systematic review and meta-analysis. J Med Internet Res. 2016 Nov 25;18(11):e310 [FREE Full text] [doi: 10.2196/jmir.5778]

116. Deo SV, Marsia S, McAllister DA, Elgudin Y, Sattar N, Pell JP. The time‑varying cardiovascular benefits of glucagon‑like peptide‑1 receptor agonist therapy in patients with type 2 diabetes mellitus: Evidence from large multinational trials. Diabetes Obes Metabol. 2022 May 23;24(8):1607-1616 [doi: 10.1111/dom.14738]

117. Mannucci E, Dicembrini I, Nreu B, Monami M. Glucagon‑like peptide‑1 receptor agonists and cardiovascular outcomes in patients with and without prior cardiovascular events: an updated meta‑analysis and subgroup analysis of randomized controlled trials. Diabetes Obes Metab. 2019 Oct 24;22(2):203-211 [doi: 10.1111/dom.13888]

118. Mannucci E, Gallo M, Giaccari A, Candido R, Pintaudi B, Targher G, et al. Effects of glucose‑lowering agents on cardiovascular and renal outcomes in subjects with type 2 diabetes: an updated meta‑analysis of randomized controlled trials with external adjudication of events. Diabetes Obes Metab. 2022 Oct 24;25(2):444-453 [doi: 10.1111/dom.14888]

119. Nguyen B, Nguyen L, Mital S, Bugden S, Nguyen HV. Comparative efficacy of sodium-glucose co-transporter-2 inhibitors, glucagon-like peptide-1 receptor agonists and non-steroidal mineralocorticoid receptor antagonists in chronic kidney disease and type 2 diabetes: a systematic review and network meta-analysis. Diabetes Obes Metab. 2023 Feb 22;25(6):1614-1623 [doi: 10.1111/dom.15009]

120. Giugliano D, Ceriello A, De Nicola L, Perrone‑Filardi P, Cosentino F, Esposito K. Primary versus secondary cardiorenal prevention in type 2 diabetes: which newer anti‑hyperglycaemic drug matters? Diabetes Obes Metab. 2019 Oct 17;22(2):149-157 [doi: 10.1111/dom.13881]

121. Chilton RJ. Effects of sodium‑glucose cotransporter‑2 inhibitors on the cardiovascular and renal complications of type 2 diabetes. Diabetes Obes Metab. 2019 Aug 30;22(1):16-29 [doi: 10.1111/dom.13854]

122. Giugliano D, Longo M, Caruso P, Maiorino MI, Bellastella G, Esposito K. Sodium-glucose co-transporter-2 inhibitors for the prevention of cardiorenal outcomes in type 2 diabetes: an updated meta-analysis. Diabetes Obes Metab. 2021 Mar 30;23(7):1672-1676 [doi: 10.1111/dom.14374]

123. Ji L, Hu D, Pan C, Weng J, Huo Y, Ma C, et al. Primacy of the 3B approach to control risk factors for cardiovascular disease in type 2 diabetes patients. Am J Med. 2013 Oct;126(10):925.e11-925.e22 [doi: 10.1016/j.amjmed.2013.02.035]

124. Strain WD, Blüher M, Paldánius P. Clinical inertia in individualising care for diabetes: is there time to do more in type 2 diabetes? Diabetes Ther. 2014 Aug 12;5(2):347-354 [doi: 10.1007/s13300-014-0077-8]

125. Ostbye T, Yarnall KSH, Krause KM, Pollak KI, Gradison M, Michener JL. Is there time for management of patients with chronic diseases in primary care? Ann Fam Med. 2005 May 01;3(3):209-214 [FREE Full text] [doi: 10.1370/afm.310] [Medline: 15928223]

126. Khunti K, Gomes MB, Pocock S, Shestakova MV, Pintat S, Fenici P, et al. Therapeutic inertia in the treatment of hyperglycaemia in patients with type 2 diabetes: a systematic review. Diabetes Obes Metab. 2017 Oct 25;20(2):427-437 [doi: 10.1111/dom.13088]

127. Etminani K, Tao Engström A, Göransson C, Sant'Anna A, Nowaczyk S. How behavior change strategies are used to design digital interventions to improve medication adherence and blood pressure among patients with hypertension: systematic review. J Med Internet Res. 2020 Apr 9;22(4):e17201 [doi: 10.2196/17201]

128. Middleton B, Sittig DF, Wright A. Clinical decision support: a 25 year retrospective and a 25 year vision. Yearb Med Inform. 2018 Mar 06;25(S 01):S103-S116 [doi: 10.15265/iys-2016-s034]

129. Shrivastav M, Gibson W, Shrivastav R. Type 2 diabetes management in primary care: the role of retrospective, professional continuous glucose monitoring. Diabetes Spectr Publ Am Diabetes Assoc. 2018;31(3):279-287 [doi: 10.2337/ds17-0024]

130. Rushforth B, McCrorie C, Glidewell L, Midgley E, Foy R. Barriers to effective management of type 2 diabetes in primary care: qualitative systematic review. Br J Gen Pract. 2016 Jan 28;66(643):e114-e127 [doi: 10.3399/bjgp16x683509]

131. Shrivastava SR, Shrivastava PS, Ramasamy J. Role of self-care in management of diabetes mellitus. J Diabetes Metab Disord. 2013 Mar 05;12(1):14 [FREE Full text] [doi: 10.1186/2251-6581-12-14] [Medline: 23497559]

132. Sirajuddin AM, Osheroff JA, Sittig DF, Chuo J, Velasco F, Collins DA. Implementation pearls from a new guidebook on improving medication use and outcomes with clinical decision support. Effective CDS is essential for addressing healthcare performance improvement imperatives. J Healthc Inf Manag. 2009;23(4):38-45 [FREE Full text] [Medline: 19894486]

133. Schuh C, de Bruin JS, Seeling W. Clinical decision support systems at the Vienna General Hospital using Arden syntax: design, implementation, and integration. Artif Intell Med. 2018 Nov;92:24-33 [doi: 10.1016/j.artmed.2015.11.002]

134. Carroll C, Marsden P, Soden P, Naylor E, New J, Dornan T. Involving users in the design and usability evaluation of a clinical decision support system. Comput Methods Programs Biomed. 2002 Aug;69(2):123-135 [doi: 10.1016/s0169-2607(02)00036-6] [Medline: 12100792]

135. Nino V, Claudio D, Schiel C, Bellows B. Coupling wearable devices and decision theory in the United States emergency department triage process: a narrative review. IJERPH. 2020 Dec 21;17(24):9561 [doi: 10.3390/ijerph17249561]

136. Boxwala AA, Kim J, Grillo JM, Ohno-Machado L. Using statistical and machine learning to help institutions detect suspicious access to electronic health records. J Am Med Inform Assoc. 2011 Jul 01;18(4):498-505 [doi: 10.1136/amiajnl-2011-000217]

137. Wiwatkunupakarn N, Aramrat C, Pliannuom S, Buawangpong N, Pinyopornpanish K, Nantsupawat N, et al. The integration of clinical decision support systems into telemedicine for patients with multimorbidity in primary care settings: scoping review. J Med Internet Res. 2023 Jun 28;25:e45944 [doi: 10.2196/45944]

138. Roshanov PS, Misra S, Gerstein HC, Garg AX, Sebaldt RJ, Mackay JA, et al. Computerized clinical decision support systems for chronic disease management: a decision-maker-researcher partnership systematic review. Implement Sci. 2011 Aug 03;6(1):92-107 [doi: 10.1186/1748-5908-6-92]

Abbreviations

AI: artificial intelligence
CDSS: clinical decision support system
CVD: cardiovascular disease
DBP: diastolic blood pressure
EHR: electronic health record
GV: glucose variability
HbA1c: glycated hemoglobin
HCP: health care provider
LDL: low-density lipoprotein
MBG: mean blood glucose
ML: machine learning
PCT: pragmatic clinical trial
PRISMA-ScR: Preferred Reporting Items for Systematic Reviews and Meta-Analyses Extension for Scoping Reviews
RCT: randomized controlled trial
RQ: research question
SBP: systolic blood pressure
ScR: scoping review
TIR: time in range