International Journal of Diabetes in Developing Countries (2023) 43:338–346
https://doi.org/10.1007/s13410-022-01115-x

REVIEW ARTICLE

Telemedicine with advanced communication technology in management of type 2 diabetes mellitus: a network meta-analysis

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Received: 20 October 2021 / Revised: 17 May 2022 / Accepted: 29 June 2022 / Published online: 9 August 2022

Abstract

Background Type 2 diabetes mellitus has risen to one of the most common chronic diseases worldwide, which puts heavy pressure on patients and the health-care system. Self-management is an important treatment for type 2 diabetes. New self-management treatments have been making great progress with the development of the advanced telemedicine.

Objective The purpose of this study is to gauge and examine the blood glucose control of various self-management strategies through a network meta-analysis.

Methods We search the articles through PubMed, Cochrane library, MEDLINE, and EMBASE databases to seek out randomized controlled trials, and the primary outcome was the change in HbA1c from baseline. This meta-analysis was conducted to compare different kinds of self-management methods, applying Revman 5.3, Stata 14.0 software, and GeMTC 0.14.3.

Results Thirty-five studies were included, consisting of 5554 type 2 diabetes mellitus patients and 4 interventions including computer-based self-management, telephone-based self-management, telemonitoring self-management, and usual care of clinic. In addition to performance bias, the risk of bias of included studies was low. In network meta-analysis, the computer-based self-management has the highest probability to be the most effective way in diabetes self-management treatments.

Conclusion In conclusion, computer-based, telephone-based, and telemonitoring self-management methods are effective self-management methods for type 2 diabetes mellitus. The computer-based self-management method was the most effective compared to the other two self-management methods.

Clinical trial registration The detailed protocol was registered in PROSPERO (https://www.crd.york.ac.uk/PROSPERO). Registration number was CRD42020186839.

Keywords Type 2 diabetes mellitus · Self-management · Computer · Telephone · Nurse

Introduction

Type 2 diabetes mellitus (T2DM) is a common chronic disease in the world, which is characterized by high incidence of complications, especially in developing countries. It is estimated that the global population with type 2 diabetes will exceed 9% in 2035 [1]. As the UKPDS mentions, the greater the population of type 2 diabetes in the world, the greater the pressure and burden on patients and health systems will be [2, 3]. Diabetes can cause a variety of complications, majorly including myocardial infarction, stroke, diabetic peripheral neuropathy, diabetic retinopathy, diabetic nephropathy, and diabetic autonomic neuropathy. These complications are common in patients with poor glycemic control, leading to higher rates of disability and mortality in this population. Diabetes self-management education and support (DSMES) provides diabetic patients with sustainable assistance, which mainly includes information and knowledge of diabetes to encourage patients' autonomy to self-manage their diabetes. The DEMES, consisting of education and support for patient self-management, is a management approach that improves health outcomes and the quality of life. According to previous studies, self-management not only plays an important role in blood glucose control, but also can prevent and delay the

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occurrence of diabetes-related complications. What's more, self-management is an important treatment for type 2 diabetes clinically. The support for self-management of diabetes is mainly provided through the daily care and clinical daily care of diabetic patients, which can help diabetic patients from the aspects of clinical problems, educational problems, social psychological problems, and behavioral problems. Due to a lack or delay in communication between patients and health care providers in usual nursing, the achievement of the blood glucose control target was far from satisfactory with the support of patient's health care team [4].

In recent years, with the development of medical care technology, self-management has been greatly developed. New self-management methods emerge in an endless stream, including the computer, mobile phone, mobile health, artificial intelligence, telemedicine, and other technologies [1, 2, 5]. As the examples of previous studies show, through these virtual diabetes care, a large amount of data from the diabetes patients can be collected and processed, such as vital signs, symptoms, and blood glucose. These specific technologies can facilitate the communication, examination, and treatment redirection, which enables the appropriate clinical decision to be made according to individual conditions. As the American Association of Diabetes Educators recommends, these interventions can enhance diabetes education, improve compliance, improve metabolic control, and raise the management efficiency of diabetes [6–8] .

However, the effects of these self-management studies were examined by direct comparison studies or traditional meta-analyses. As far as we know, traditional meta-analysis evaluates only a single intervention which makes clinicians confused when choosing a reasonable self-management plan. Based on the previous randomized controlled trials of self-management, the network meta-analysis was designed to comprehensively value the various self-management for T2DM in the present study [9].

Method

Protocol and registration

The elaborated protocol was registered in website of PROSPERO. Registration number was CRD42020186839. Our meta-analysis was consistent with the PRISMA statement and also the network meta-analysis extension statement of PRISMA.

Literature search

PubMed, Cochrane library, MEDLINE, and EMBASE databases (inception–2nd May, 2020) were used for retrieval, with "Type 2 diabetes mellitus" and "Self-management intervention" as key words. The search criteria were randomized controlled trials (RCTs) and reported in English language. The search strategies in details were displayed in supplementary file 1.

Inclusion criteria and exclusion criteria

The inclusion criteria used for selection of studies were listed as follows: (1) the patients of type 2 diabetes mellitus; (2) self-management interventions were based on advanced technologies, including computer-based interventions, APPs, telemedicine, mobile health and so on; (3) the main outcome was the change in HbA1c from baseline; (4) studies were limited to randomized controlled trials (RCTs). We excluded studies that met any of the following criteria: (1) non-randomly control trial was excluded, including cohort study, case-control study, case reports, case series, and narrative reviews; (2) cluster randomly control trial; (3) publications in non-English languages; (4) publications that did not provide sufficient data; (5) type 1 diabetes mellitus and pregnant diabetes; (6) animal experiments. Considering that there may be multiple papers published in the overlapping cohort, the latest results with the largest sample size will be selected for statistical analysis in this study.

Selection of studies

During the primary screening process, two reviewers independently screened the citation titles and abstracts to reserve relevant studies and examined each potential study through the full text individually in the secondary screening. Subsequently, the other two reviewers evaluated all relevant studies based on the inclusion and exclusion criteria. If there was any contradiction, the third author would be consulted on the solutions.

Assessment of study quality and data extraction

The risk of bias in the included studies was assessed using the Cochrane risk bias instrument which is commonly used tool in RCT quality assessment (the section that is being explained in detail of Cochrane was deleted).

This study extracted the following information and data from the included articles, mainly including the name of the author, the year of article publication, sample size, specific self-management, and HbA1c.

Two reviewers finished the quality assessment and data extraction. If there was any contradiction, the third author would be consulted on solutions.

Statistical analysis

We performed the pairwise meta-analysis and Bayesian NMA to investigate the efficacy of self-management in patients with T2DM, applying Revman 5.3 (Cochrane Collaboration, Oxford, UK), Stata 14.0 software (StataCorp LP, College Station, TX, USA), and GeMTC 0.14.3 (MRC Biostatistics Unit, Cambridge, UK). Standardized mean difference (SMD) with 95% confidence interval (CI) was calculated and reported to assess the efficacy of competing self-management methods for T2DM. Each self-management measure was carried out through the traditional pairwise meta-analysis of random effects [9]. The Bayesian model was used to sort the included measures, running 50,000 iterations for each of 4 chains, of which the first 20,000 iterations were used as burn-in. The surface under the cumulative ranking curve (SUCRA) was performed to evaluate the blood glucose control of the self-management for T2DM. We adopted the split-node method to check the existence of inconsistency [4]. Funnel charts were drawn to investigate the potential publication bias among the included studies [10].

Result

Selection of studies and characteristics of included studies

After removing duplicate studies, we preliminarily screened out 1349 original studies from the initial online search, of which 95 studies met the titles and abstract criteria. We subsequently read and evaluated the full text of these articles, and 60 of them were excluded for the following reasons: (1) repeated publication (N=2); (2) without valid data (N=45); (3) non-randomly control trial (N=4); (4) cluster randomly control trial (N=9). Finally, the remaining 35 studies were included in the current network meta-analysis according to the inclusion and exclusion criteria. The flowchart of the literature screening process was shown in Fig. 1. Table 1 summarized the characteristics of the included literature in this study

Methodological quality

Different self-management methods were not disguised as the same name, so that the participants were aware of their group after assigning tasks. According to the Cochrane risk of bias instrument, the included studies were judged to have high risk of performance bias due to the lack of blinding among personnel and participants. Further ambiguous risk biases were found through large proportion of studies within the domains of selection bias, including 16 of 35 studies (46%) in random sequence generation and 22 of 35 studies (63%) in allocation concealment. About 29 (83%) of 35 studies were assessed as having an unclear risk of detection bias. Additionally, all studies had ambiguous risk of bias in other. All studies have low risk of attrition bias, and 34 of 35 studies (97%) were considered as low risk of reporting bias. As shown in supplementary file 2, the final quality of the included studies indicated the relatively low risk of bias, which provided credible evidence for the outcome of meta-analysis.

Comparison of glycemic management

Thirty-five studies [6, 11–44] were included for data, consisting of 5554 T2DM patients and 4 interventions including computer-based self-management, telephone-based self-management, telemonitoring self-management, and usual care of clinic. The weighted network was presented in Fig. 2. The standardized mean difference (SMD) was used to evaluate the difference of blood glucose control effect of different self-management intervention methods. For the results obtained from the random effects standard deviation analysis, the consistency model of 0.33 (0.23, 0.49) was like the inconsistency model of 0.32 (0.21, 0.47), and the inconsistency standard deviation was 0.66 (0.03, 1.64). What's more, through the node-splitting analysis of Bayesian framework, there was a good consistency between direct comparison and indirect comparison in most of the included studies. The result of node-splitting analysis was presented in supplementary file 3. In traditional meta-analysis, statistical significance of traditional pairwise comparison was found in computer-based self-management of −0.53 (−0.71, −0.34) versus usual care, telemonitoring self-management of -0.25 (−0.43, −0.06) versus usual care, and telephone-based self-management of −0.42 (−0.52, −0.31) versus usual care. The differences in the efficacy of self-management interventions on blood glucose control were evaluated by network meta-analysis of Bayesian framework, as shown in Table 2. And the rank of the efficacy was presented in Fig. 3. According to Surface Under the Cumulative Ranking (SUCRA) shown in Table 3, the computer-based self-management method ranks first in the blood glucose control of patients with type 2 diabetes. As shown in Fig. 4 for comparison-adjusted funnel plot, the funnel graph illustrated that publication bias existed in the included studies, but the risk of publication bias could be considered low.

Discussion

To our knowledge, this was the first study to apply network meta-analysis to comprehensively evaluate the blood glucose control of different self-management interventions for patients with T2DM. We found that computer-based self-management, telephone-based self-management, and telemonitoring self-management were stronger blood glucose control than

Table 1 Characteristics of studies selected for meta-analyses

Study description					HbA1c reduction			
					Treatment group		Control group	
Source	Study location	Length of follow-up	Intervention	*N* (total)	Mean (SD)	*n*	Mean (SD)	*n*
Cho2006 [11]	Korea	30 months	Computer vs. usual care	80	−1 (1.308)	40	−0.1 (1.3)	40
Dario2017 [6]	Italy and Belgium	12 months	Telemonitoring vs. usual care	246	−0.26 (0.92)	168	−0.27 (0.99)	78
Döbler2018 [12]	German	12 months	Telephone vs. usual care	199	−0.68 (1.4)	98	0.12 (1.7)	101
Faridi2008 [13]	USA	3 months	Telephone vs. usual care	30	−0.1 (0.3)	15	0.3 (1)	15
Fortmann2017 [14]	Canada	6 months	Telephone vs. usual care	126	−1 (1.2)	63	−0.2 (1.778)	63
Kleinman2017	India	6 months	Telephone vs. usual care	90	−1.5 (1.1)	44	−0.8 (1.6)	46
Mcmahon2012 [16]	USA	12 months	Computer vs. telephone	102	−1.3 (1.4)	51	−1.5 (1.6)	51
Pressman2014 [17]	USA	6 months	Telemonitoring vs. usual care	225	−2 (1.8)	118	−1.8 (1.7)	107
Sun2019 [18]	China	6 months	Telephone vs. usual care	91	−1 (0.745)	44	−0.66 (0.781)	47
Tang2013 [19]	USA	12 months	Computer vs. usual care	415	−1.14 (1.637)	202	−0.95(1.776)	213
Stone2010 [20]	USA	6 months	Telemonitoring vs telephone	137	−1.7 (1.442)	64	−0.8 (1.353)	73
Vinitha2019 [21]	India	24 months	Telephone vs. usual care	248	−2.1 (1.873)	126	−1.7 (1.735)	122
Wang2019 [22]	China	6 months	Telephone vs. usual care	120	−1.5 (2.188)	60	−0.76 (2.207)	60
Wild2016 [23]	UK	9 months	Telemonitoring vs. usual care	285	−1 (1.353)	146	−0.4 (1.212)	139
Yoo2009 [24]	Korea	3 months	Telephone vs. usual care.	111	−0.5 (0.854)	57	0.2 (0.954)	54
Zhou2014 [25]	China	3 months	Computer vs. usual care	108	−1.6 (1.428)	53	−0.62 (1.575)	55
Cho2017 [26]	Korea	6 months	Telemonitoring vs. usual care	484	−0.31 (0.7)	244	−0.11 (0.76)	240
Hansel2017 [27]	France	4 months	Computer vs. usual care	120	−0.3 (0.94)	60	0.21 (0.7)	60
Jeong2018 [28]	Korea	24 weeks	Computer vs. telemonitoring	338	−0.81 (1.05)	112	−0.66 (1.09)	113
Jeong2018 [28]	Korea	24 weeks	Computer vs. usual care	338	−0.81 (1.05)	112	−0.66 (1.03)	113
Kwon2004 [29]	Korea	12 weeks	Computer vs. usual care	110	−0.65 (1.257)	55	0.43 (1.067)	55
Avdal2011 [30]	Turkey	6 months	Computer vs. usual care	122	−0.512 (0.875)	61	0.048 (1.08)	61
Cho2011 [31]	Korea	12 weeks	Compute vs. usual care	71	−0.5 (0.854)	36	−0.2 (1.054)	35
Duruturk2019 [32]	Turkey	6 weeks	Computer vs. usual care	44	−1.21 (1.277)	23	0.35 (2.478)	21
Kim2006 [33]	Korea	12 weeks	Computer vs. usual care	51	−0.59 (0.61)	28	0.43 (0.81)	23
Kim2016 [34]	China	5 months	Computer vs. usual care	182	−1.2 (0.7)	92	−0.6 (1.136)	90
Nicolucci2015 [35]	Italy	12 months	Telemonitoring vs. usual care	302	−0.5 (0.917)	153	−0.21 (0.985)	149
Crowley2016 [36]	USA	6 months	Telephone vs. usual care	50	−1.30 (1.685)	25	−0.3 (1.685)	25
Davis RM2010 [44]	USA	12 months	Telephone vs. usual care	165	−1.2 (3.324)	85	−0.2 (3.225)	80
Kempf2017 [37]	Germany	12 weeks	Telemonitoring vs. usual care	167	−1.1 (1.2)	93	−0.2 (0.8)	74
Anzaldo-Campos2016 [38]	Mexico	10 months	Telephone vs. usual care	202	−3.02 (2.83)	102	−1.3 (3.29)	100
Bujnowska-fedak2011 [39]	Poland	6 months	Computer vs. usual care	95	−0.26 (1.418)	47	−0.18 (1.576)	48
Wakefield2014 [40]	USA	12 weeks	Telemonitoring vs. usual care	94	0.1 (1.314)	41	0 (1.276)	53
Xu2019 [41]	USA	6months	Telephone vs. usual care	37	−0.69 (1.482)	19	−0.03 (1.744)	18
Yu2019 [42]	China	24 weeks	Telephone vs. usual care	95	−1.1 (0.3)	48	−1.1 (0.4)	47
Wang2019 [43]	China	6months	Computer vs. usual care	212	−1.1 (0.7)	106	−0.6 (1.136)	106

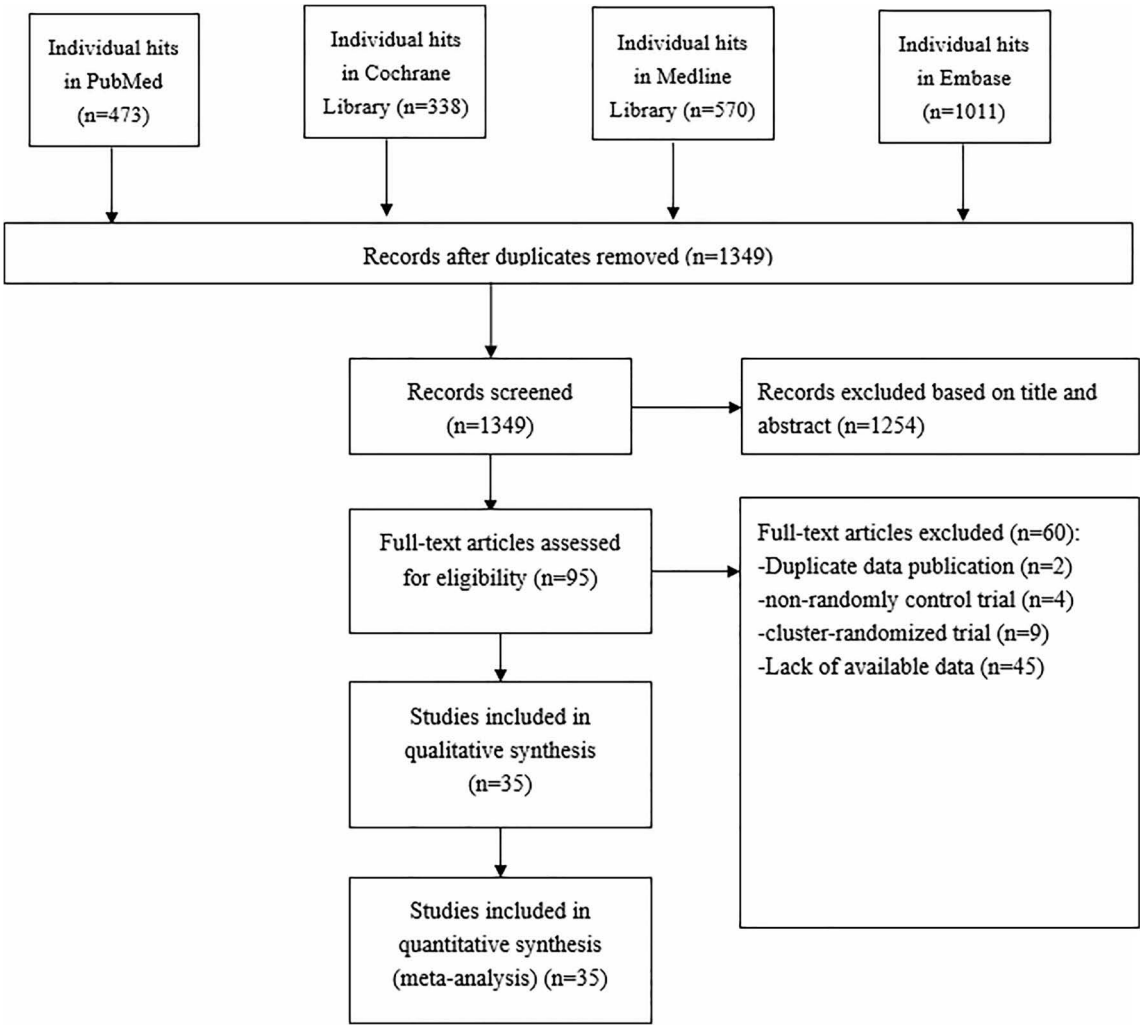

Fig. 1 PRISMA flow diagram

placebo in blood glucose management, and computer-based method was the strongest blood glucose control self-management method among them.

As far as we know, the network meta-analysis can provide the most comprehensive data analysis for advanced self-managements of T2DM patients. In our network meta-

Table 2 Comparisons of different categories of self-management

Standardized mean difference using traditional pairwise meta-analysis				
Standardized mean difference with network meta-analysis	computer	-	-	**-0.53 (-0.71, -0.34)**
	-0.18 (-0.52, 0.14)	telemonitoring	-	**-0.25 (-0.43, -0.06)**
	-0.04 (-0.35, 0.27)	0.14 (-0.18, 0.47)	telephone	**-0.42 (-0.52, -0.31)**
	-0.58 (-0.80, -0.36)	**-0.4 (-0.65, -0.15)**	**-0.54 (-0.78, -0.31)**	usual-care

The row and column values in the matrix represent the difference between the standardized averages of different self-management intervention. The statistics are expressed as standardized mean difference SMD (lower 95%CI, upper 95%CI). Statistically significant SMDS are highlighted in bold

Table 3 Surface under the cumulative ranking (SUCRA)

Intervention	SUCRA	PrBest	MeanRank
Computer	91.9	80.0	1.2
Telemonitoring	51.0	7.7	2.5
Telephone	57.1	12.3	2.3
Usual care	0.0	0.0	4.0

analysis, the included studies were tested using different methods. The percentage of changes of glycosylated hemoglobin before and after self-management was evaluated by SMD method. The evidence of meta-analysis was obtained from direct and indirect comparison tests. According to the node-splitting analysis of Bayesian framework, only 9 studies [6, 17, 20, 23, 26, 28, 35, 37, 40] showed statistical significance in direct and indirect comparison in telemonitoring self-management. The random effects standard deviation of both consistency model and inconsistency were similar in our network meta-analysis [45]. What's more, there was a difference between the random effects standard deviation and inconsistency standard deviation in inconsistent examination. In general, these examinations demonstrated good consistency in the included studies, so the data can be pooled for network meta-analysis. According to the SUCRAs and comprehensive ranking, computer-based self-management, telephone-based self-management, and telemonitoring self-management displayed substantial effects on blood glucose control of patients with T2DM. The result of our network meta-analysis was consistent with previous studies [1, 2].

As the abovementioned effective test of self-management showed, what these different self-management methods had in common was the use of advanced technology. The computer-based self-management, telephone-based self-management, and telemonitoring self-management involved several aspects of achieving blood glucose goals, including glycemic telemonitoring, physical activity, diabetes self-management education, and compliance [19, 22, 23]. All advanced self-management interventions can provide patients with a convenient way, which enables patients to get immediate assistance and make personalized blood glucose control programs at any time. Meanwhile, due to the infrequent or delayed contact between patients and health providers in usual care, patients might miss the best time for treatment [36]. Therefore, advanced self-management treatments might play an important part in the outcome that the computer-based self-management, telephone-based self-management, and telemonitoring self-management were more effective than usual care in glycemic control.

As the third strongest blood glucose control self-management in our network meta-analysis, the telemonitoring self-management used advanced technology to load data into the remote center of the health care provider through a personal modem. But there was usually a fixed time during which the health care provider processed patient data on a regular basis. Patients must wait for a reply from the health provider and there was a lack of direct contact between the patient and

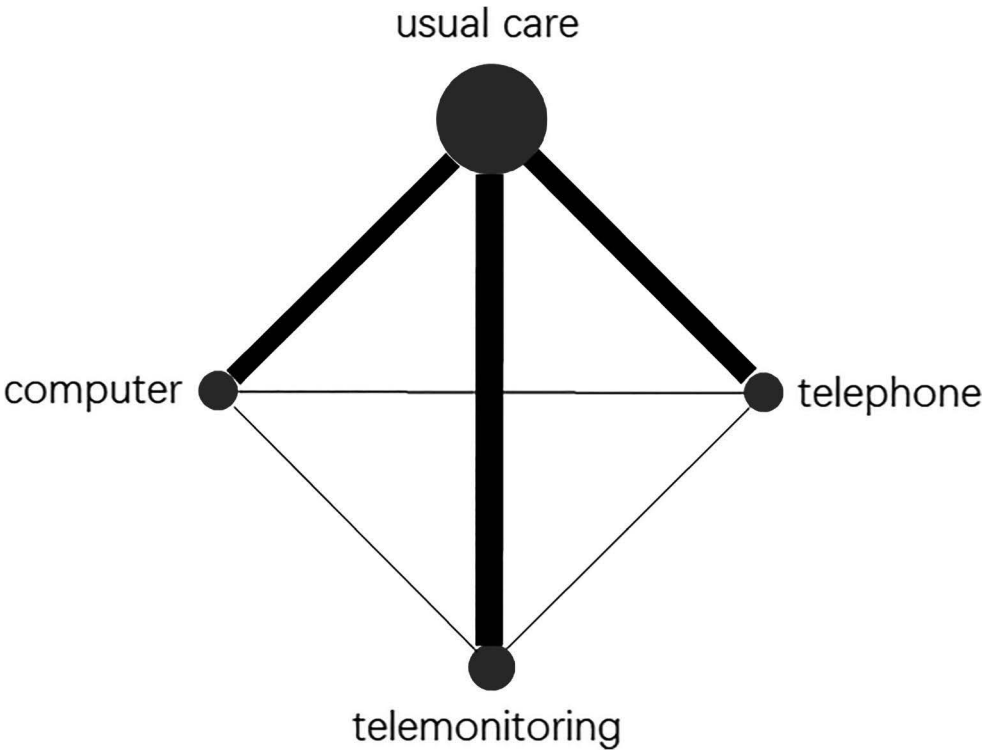

Fig. 2 Risk of bias summary: reviewers' judgments for each included trial about each risk of bias item

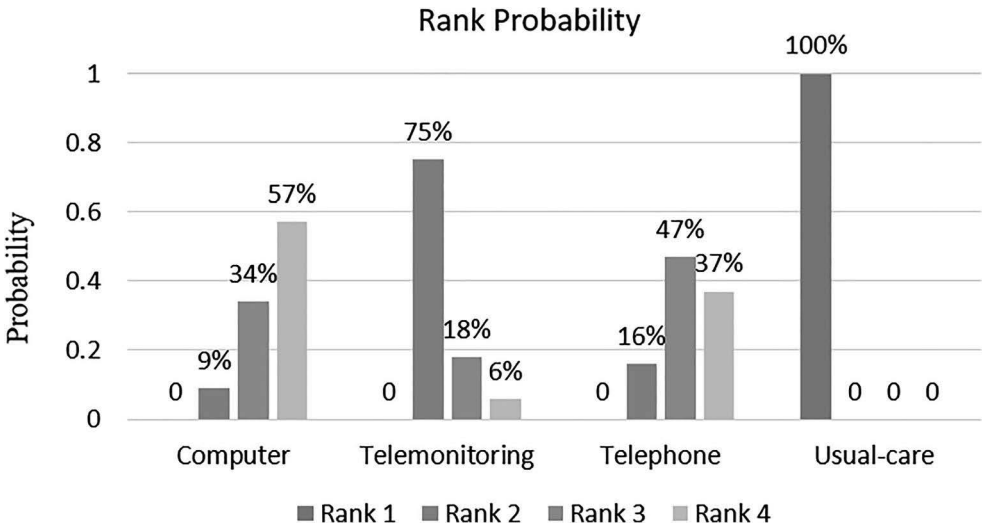

Fig. 3 Diagrams of rank analysis of efficacy comparisons

the provider. Besides, some of telemonitoring self-management still used clinical way to provide patient–provider contact [23, 26, 31]. Therefore, the blood glucose control of telemonitoring self-management was poorer than the computer-based self-management and telephone-based self-management.

For the included telephone-based self-management research, part of the research used mobile applications [18, 22, 46], and the other part of those research was based on the telephone communication and short message service [12, 21]. Providing counseling to patients through telephone communication and short message service can increase the enthusiasm of patients, while mobile applications or Internet software can provide complete guidance [16, 34]. And all of the computer-based self-management studies established a complete glycemic management system through the diabetes guidelines. Therefore, the computer-based self-management might be more effective in glycemic control than telephone-based self-management, which was consistent with the result of our network meta-analysis.

Although computer-based self-management was the most effective approach, there were still some advantages in other self-managements. With the development of technology, advanced self-management was no longer restricted by its own characteristics. For example, the telemonitoring device can provide communication function [26], and the smartphones

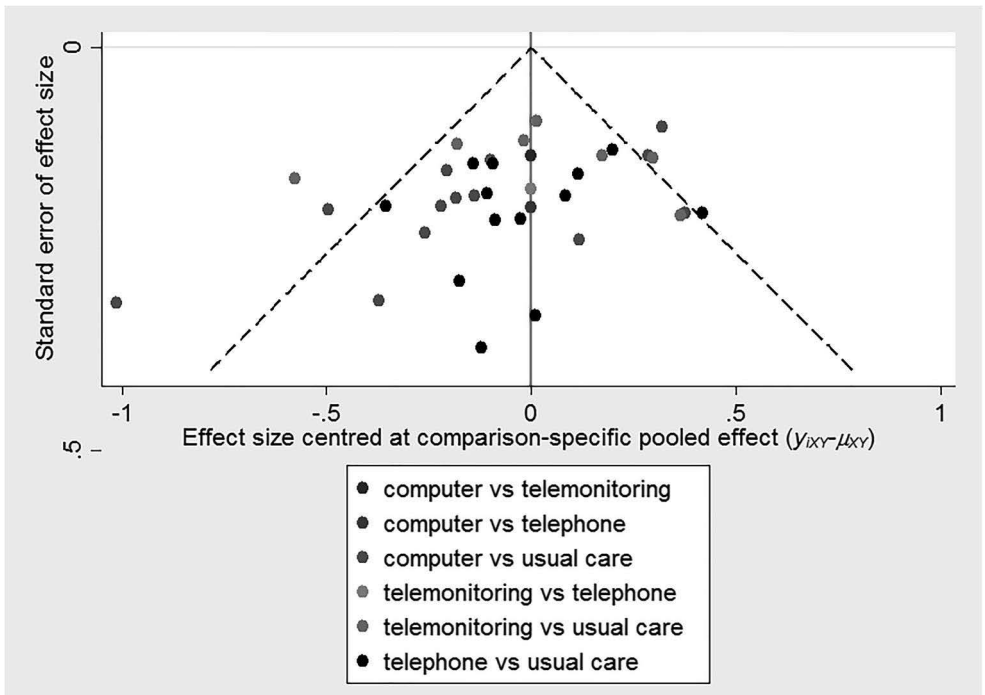

Fig. 4 The comparison-adjusted funnel plot

can provide full-featured mobile applications for T2DM patients through Internet services [18, 22]. The use of computers for self-management has not only been proved to be effective in controlling blood glucose, but its portability has gradually emerged with the popularity of tablet computers and laptops [47]. In the future, the treatment of diabetes will no longer rely on one type of self-management. It will use a variety of advanced self-management methods to achieve glycemic goals.

The limitations of our network meta-analysis were listed as follows: (1) Due to the inconsistency, the results of network meta-analysis might cause deviation; (2) only studies published in English were evaluated; (3) in the case of publication bias, some trials with negative results may not be published, so the evaluation may be biased; (4) the performers and participants were not blinded in all of the included studies so that the outcome of RCT might be impacted by artificiality; (5) lack of head-to-head trial of self-management methods.

Conclusion

The computer-based self-management was preferable to other self-management methods for T2DM. Compared to the other two self-management methods, the computer-based self-management method was the most effective. The effective self-management may be based on the strong functions of the computer. With the development of advanced technology, mHealth, or other convenient technology containing computer functions will be the potential way to the diabetes self-management in the future. More head-to-head studies with larger sample size and longer trial period are warranted to support our findings and explore the efficacy of advanced self-management treatments. In the future research, the cost of different self-management methods should also be regarded as one of the influencing factors of effectiveness evaluation.

Supplementary Information The online version contains supplementary material available at https://doi.org/10.1007/s13410-022-01115-x.

Declarations

Conflict of interest and Source of Funding None

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