RESEARCH ARTICLE

The effectiveness of diabetes self-management education intervention on glycaemic control and cardiometabolic risk in adults with type 2 diabetes in low- and middle-income countries: A systematic review and meta-analysis

Hasina Akhter Chowdhury[1,2]*, Cheryce L. Harrison[3], Bodrun Naher Siddiquea[1], Sanuki Tissera[1], Afsana Afroz[4], Liaquat Ali[5], Anju E. Joham[3,6], Baki Billah[1]

1 Department of Epidemiology and Preventive Medicine, School of Public Health and Preventive Medicine, Monash University, Melbourne, Australia, 2 Centre for Injury Prevention and Research, Bangladesh (CIPRB), Dhaka, Bangladesh, 3 Monash Centre for Health Research and Implementation–MCHRI, School of Public Health and Preventive Medicine, Monash University, Melbourne, Australia, 4 Department of Biochemistry and Pharmacology, Faculty of Medicine, Dentistry and Health Sciences, The University of Melbourne, Melbourne, Australia, 5 Pothikrit Institute of Health Studies (PIHS), Dhaka, Bangladesh, 6 Departments of Endocrinology and Diabetes, Monash Health, Melbourne, Australia

* hasina.chowdhury@monash.edu

Abstract

Diabetes mellitus (DM) poses a significant challenge to public health. Effective diabetes self-management education (DSME) interventions may play a pivotal role in the care of people with type 2 diabetes mellitus (T2DM) in low- and middle-income countries (LMICs). A specific up-to-date systematic review is needed to assess the effect of DSME interventions on glycaemic control, cardiometabolic risk, self-management behaviours, and psychosocial well-being among T2DM across LMICs. The MEDLINE, Embase, CINAHL, Global Health, and Cochrane databases were searched on 02 August 2022 and then updated on 10 November 2023 for published randomised controlled trials (RCTs) and quasi-experimental studies. The quality of the studies was assessed, and a random-effect model was used to estimate the pooled effect of diabetes DSME intervention. Heterogeneity (I^2) was tested, and subgroup analyses were performed. Egger's regression test and funnel plots were used to examine publication bias. The risk of bias of the included studies was assessed using the Cochrane risk-of-bias tool for randomized trial (RoB 2). The overall assessment of the evidence was evaluated using the Grading of Recommendations Assessment, Development, and Evaluation approach. A total of 5893 articles were retrieved, and 44 studies (n = 11838) from 21 LMICs met the inclusion criteria. Compared with standard care, pooled analysis showed that DSME effectively reduced the HbA1c level by 0.64% (95% CI: 0.45% to 0.83%) and 1.27% (95% CI: -0.63% to 3.17%) for RCTs and quasi-experimental design studies, respectively. Further, the findings showed an improvement in cardiometabolic risk reduction, diabetes self-management behaviours, and psychosocial well-being. This review

suggests that ongoing support alongside individualised face-to-face intervention delivery is favourable for improving overall T2DM management in LMICs, with a special emphasis on countries in the lowest income group.

Introduction

Diabetes mellitus (DM) is a prevalent public health concern [1], with an estimated 537 million (10.5%) adults aged between 20 to 79 affected globally in 2021 [2]. Among those adults, approximately 90% had type 2 diabetes (T2DM) [2, 3]. T2DM is the primary cause of major micro- and macro-vascular complications contributing to significant adverse clinical sequelae, including premature death [4]. In recent decades, the prevalence of T2DM has escalated more rapidly in low- and middle-income countries (LMICs) compared with high-income countries (HICs), with an estimated 79.4% of the global T2DM population residing in LMICs [2]. In 2021, the estimated global annual cost of diabetes treatment was 966 billion USD [2], imposing a substantial health and economic burden on individuals, their families, and healthcare systems [5–10].

The cornerstone of T2DM management is controlling glycosylated haemoglobin (HbA1c) and optimising cardiometabolic risk factors [11]. Self-management of healthy lifestyle strategies, typically involving optimisation of diet, increasing physical activity, and weight loss in those who are overweight and obese, are recommended as first-line interventions; however, these are highly dependent on individual health literacy, self-efficacy, and motivation [12]. For this reason, diabetes education is crucial in optimising self-management strategies by enhancing knowledge as well as by encouraging and consolidating behaviour-change skills [13, 14]. All of these can be addressed using diabetes self-management education (DSME) intervention [15–17]. DSME intervention includes educating patients through the application of self-care strategies (facilitating with the knowledge, skill and ability) in a cost-effective manner to enhance treatment adherence, diabetes self-management (diabetes knowledge and self-efficacy), lifestyle change (diet, physical activity and weight management where appropriate) and psychological well-being (health-related quality of life [HrQoL]) [15, 18, 19].

Previous systematic reviews and meta-analyses conducted in HICs demonstrate that DSME intervention is associated with improved glycaemic control, diabetes knowledge, self-efficacy, HrQoL [20–22], and reduction in all-cause mortality [23]. This includes a 0.4% reduction in HbA1c, a more than 5 mg/dl reduction in total cholesterol (TC) and a more than 1 mmol/L reduction in fasting blood glucose (FBG) when compared to standard care [24–29]. In addition, DSME intervention in HICs showed positive changes in diabetes-specific knowledge and lifestyle [30]. However, generalising evidence from HICs to LMICs needs to be interpreted with caution given cultural, ethnic, and economic disparities, as well as the variations among study populations [30, 31]. Recent reviews conducted in LMICs demonstrated that DSME intervention, short-term nutrition education and/or lifestyle modification intervention may enhance glycaemic control [30, 32–35] and anthropometric measures [33]. However, to our knowledge, limited attempts have been made in the literature to assess the effectiveness of DSME interventions on a comprehensive outcome measures in LMICs [36–39], which include the effectiveness in the change in diabetes control and cardiometabolic risk, diabetes self-management behaviours and psychosocial well-being. Thus, the aim of the present review is to comprehensively assess the effectiveness of DSME intervention on glycaemic control (eg. HbA1c/FBG), cardiometabolic risk factors (eg. WC, BMI, LDL, HDL, TC, TG, SBP, and DBP),

diabetes self-management behaviours (eg. diabetes knowledge and self-care) and psychosocial well-being (eg. health-related quality of life) among people with T2DM living in LMICs and to explore intervention characteristics, as well as their mode of delivery, frequency, intensity and duration in relation to the improvement in outcomes.

Methods

This systematic review and meta-analysis was registered with PROSPERO (CRD: 42022364447) and conducted according to the Preferred Reporting Items for Systematic Reviews and Meta-analyses (PRISMA) guidelines [40] (S1 Table).

Selection criteria

Inclusion criteria. The Participant, Intervention, Comparison, Outcome and Study type (PICOS) framework (S2 Table) informed the inclusion and exclusion criteria. Participants included adults with T2DM residing in LMICs. Any form of educational intervention (e.g. self-management intervention with a variety of educational/behavioural components and/or lifestyle modification to diet and exercise) delivered in an LMIC to people with T2DM and targeting diabetes care management compared with standard care/usual care. Outcomes included any one or combination of the following: glycaemic control (HbA1c/fasting blood glucose [FBG]), cardiometabolic risk body mass index (BMI), waist circumference (WC), high-density lipoproteins (HDL), low-density lipoproteins (LDL), triglycerides (TG), total cholesterol (TC), systolic blood pressure (SBP), diastolic blood pressure (DBP), diabetes knowledge, self-efficacy and health-related quality of life (HrQoL). The study types included either RCT or quasi-experimental designs without language or time restrictions.

Exclusion criteria. Studies reporting on type 1 diabetes and gestational diabetes were excluded. Qualitative studies, editorials, commentary, reviews and case reports were excluded.

Search strategy

Five electronic databases (MEDLINE, Embase, CINAHL, Global Health and Cochrane) were searched from their dates of inception through 02 August 2022 and updated on 10 November 2023 (S3 Table) by two authors (HAC and BNS) in consultation with a senior librarian at Monash University. A range of keywords relating to T2DM including educational intervention and model/tools of diabetes care were used, and the list of LMICs was based on the current World Bank Database [41].

Study selection process

Retrieved articles were stored and managed using the citation software EndNote X20. Following the searches, two authors (HAC and BNS) independently screened all titles as well as abstracts and excluded studies that did not meet the inclusion criteria. A total of 105 articles were selected for a comprehensive full-text review. Following a review for accuracy, two authors (HAC, and BNS) independently reviewed the full text of these 105 articles, and any discrepancy was discussed with a third author (ST) with the supervision of senior author (BB). Finally, a set of 44 articles were selected to determine final article eligibility (Fig 1). A manual search of reference lists of included studies was also performed.

Study outcomes

The primary outcome of this study was to assess any changes in glycaemic control (i.e. HbA1c or fasting blood glucose [FBG]) after intervention. Secondary outcomes were cardiometabolic
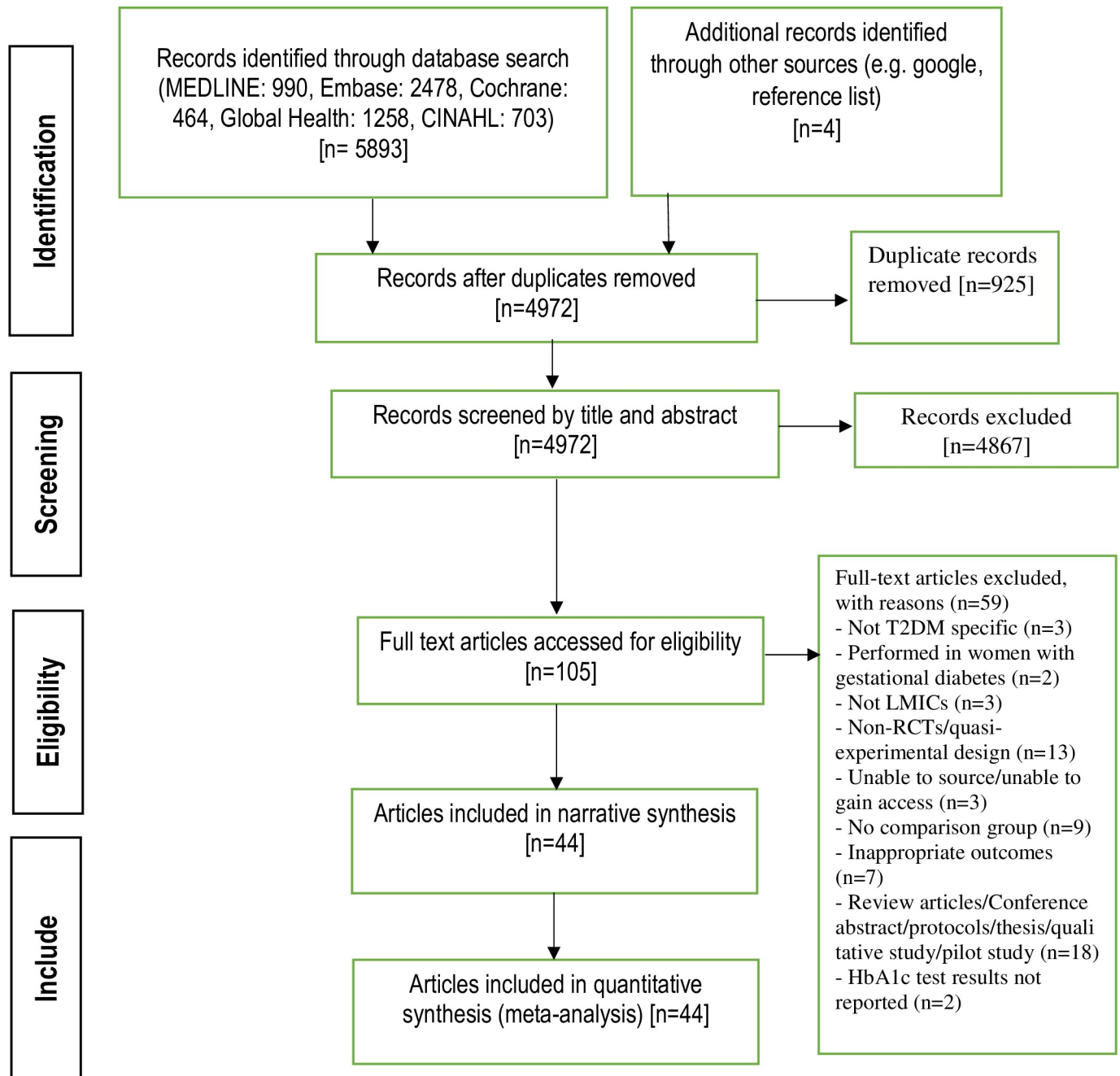
Fig 1. PRISMA flow diagram.

risk factors (i.e. BMI, WC, HDL, LDL, TG, TC, SBP or DBP), HrQoL and changes in behavioural outcomes (i.e. diabetes knowledge and self-efficacy [S4 Table]).

Data extraction

Data from the included articles were extracted independently by two authors (HAC and BNS) using Microsoft Excel. The following information was extracted: publication details (author/s, year of publication and journal), study characteristics (country, study design, setting,

population and sample size), demographics (age of the participants), details of the intervention (type, frequency, intensity, intervention format, duration, number of educational sessions, intervention provider and mode of delivery of the intervention) as well as primary and secondary outcomes (i.e. HbA1c/FBG, BMI, WC, LDL, TG, TC, SBP, DBP, diabetes knowledge, self-efficacy and HrQoL). Discrepancies were discussed and resolved through consensus or arbitration between reviewers.

Quality assessment

Study quality was appraised independently by two authors (HAC and BNS) using the revised Cochrane risk-of-bias tool for randomised trials (RoB 2) [42, 43] for randomised controlled trials, and the Joanna Briggs Institute (JBI) Critical Appraisal Checklist for quasi-experimental studies (non-randomised experimental studies) [44]. The Cochrane's RoB 2 tool evaluates randomisation process, deviations from the intended interventions, missing outcome data, measurement of the outcome, and selection of the reported result [42]. For this review, the overall risk of bias was rated as high/low/some concerns, in agreement with the RoB 2 tool. Senior author (BB) was consulted to resolve instances of disagreement. A detailed description of the quality assessment has been provided as supporting information (S5 Fig and S6 Table).

Assessment of certainty of the evidence

Grading of Recommendations, Assessment, Development, and Evaluations (GRADE) was used to evaluate the quality of the evidence [45]. GRADE pro-GDT was employed to summarise the quality of evidence [46]. The certainty of the evidence encompasses consideration of the within-study risk of bias which comprises methodological worth, indirectness of evidence, unexplained heterogeneity, imprecision and, probability of publication bias. The GRADE approach has following four levels of quality such as high-quality evidence that recommends that additional study is very unlikely to change our confidence in the estimate of effect size; moderate quality reflects further research as likely to have a vital impact on the estimate of effect size and may alter the estimate; low quality reveals that further research is very unlikely to have a significant influence on the current estimate of effect size and is likely to change the estimate; and very low quality suggests one is precise indeterminate about the estimate.

Data analysis

All statistical analyses were performed using Stata V.16 (StataCorp, College Station, Texas, USA). A random-effects model was used to estimate pooled mean differences (MD) for HbA1c or FBG and other relevant quantitative data with a 95% confidence interval (CI). Heterogeneity was tested using the $\chi2$-test on Cochran's Q statistic, which was calculated by means of H and I^2 indices. I^2 values of over 75% were considered to represent substantial heterogeneity [47]. Subgroup analyses were also performed with the covariates of income level of the country, intervention type, mode of delivery of the intervention and study quality to identify possible sources of heterogeneity. Egger's regression test and funnel plots were used to examine publication bias [48]. As standard deviation of the mean change from baseline is defined as a common missing outcome data [49], and difficulties in running a meta-analysis without missing standard deviations (SDs). The following formula was used to calculate missing SDschange [50]:

$$\text{SDchange} = \sqrt{(\text{SD}^2 \text{ baseline} + \text{SD}^2 \text{ final}) - (2 * r * \text{SD baseline} * \text{SD final})}$$. If the SDbaseline and SDfinal values were known, the SDchange value was calculated by assigning a value of 0.7 to the r in the formula, to provide a conservative estimate as undertaken by previous

systematic reviews [50]. All data are reported as a mean difference (95% confidence limits). Characteristics of the included studies are reported as mean (±SD) or number percentages as appropriate. In order to readability of the results, all p-values (where applicable) generated in the tables and forest plots have been approximated to three decimal places while reported in the results section. Statistical tests were considered significant at p-values ≤5% (≤0.05)

Results

Selection of studies

A total of 58974 articles were retrieved from the five databases (MEDLINE, Embase, Cochrane, global health and CINAHL) and manual searches. After removing duplicates through title and abstract screening, 105 articles were included for full-text review. Of those, 44 studies (n = 41 RCTs and n = 3 quasi-experimental studies) conducted in 21 LMICs that included 11,838 participants (5,887 in the intervention arm and 5,951 in the comparator arm) (Fig 1).

Characteristics of the included studies

The characteristics of the included studies are reported in Table 1. Of the 44 studies, 21 were conducted in upper-middle-income countries [51–71], 21 in lower-middle-income countries [1, 38, 72–90], and two were conducted in low-income countries [91, 92], as grouped by the World Bank criteria [41]. The studies were conducted in diabetes clinics or hospitals (n = 15 [34%]), public or private hospitals/clinics (n = 21[48%]) and community settings/home-based locations (n = 8 [18%]). All community settings/home-based studies were conducted in the upper-middle-income countries except one from a low-income country [91]. No community-based studies were conducted in the Southeast Asian region. The HbA1c was reported most frequently (n = 42 [95%] studies), followed by FBG (n = 19 [43%]), BMI (n = 23 [52%]), WC (n = 10 [23%]), LDL (n = 18 [41%]), HDL (n = 17 [39%]), TC (n = 17 [39%]), TG (n = 12 [27%]), SBP (n = 20 [45%]), DBP (n = 17 [39%]), diabetes knowledge (n = 10 [23%]), self-efficacy (n = 7 [16%]), and HrQoL (n = 6 [14%]).

The sample size in the studies ranged from 41 [92] to 1,570 [62], and the average age of the participants was 55 (SD: 6, range 42 to 71 years). The intervention durations ranged from four [59] to 348 weeks [69], with two-thirds (66.6%) of the studies lasting six months in duration. Standard care/usual care comprised the current standard of care as defined by the local programme or setting.

Intervention characteristics

Overall, the majority of interventions utilised a behaviour-change approach focused on building knowledge, self-efficacy and self-management skills through counselling, coaching, brainstorming or supporting the control of T2DM and its related complications [S5 Table]. Five trials used DM self-management-based coaching programmes [54, 67, 80, 89, 91], four trials used the empowerment approach and interactive teaching model [63, 64, 74, 76], and three used the theory of self-efficacy as a theory or model to underpin intervention content [65, 66, 68]. Each of the following models was used by one trial only: the beliefs, attitudes, subjective norms and enabling factors (BASNEF) model [72]; the predisposing, reinforcing and enabling constructs in educational diagnosis and evaluation (PRECEDE) model [78]; the chronic care model [58]; clinic-based intensified diabetes management model (C-IDM) [60]; the health-belief model [81]; the comprehensive systematic health education and promotion (SHEP) model [85]; the diabetes comprehensive care model (DCCM) [88]; the structured DSME model [38] and the lifestyle intervention holistic model (LIHM) [90]. The remaining 23 trials

Table 1. Summary characteristics of the included studies.

Sl No	First author (year)	Study design	Country	Country by income	Sample size	Study duration (in weeks)	Age in years Mean (SD)	Mode of delivery of the intervention	Intervention format	Model/theory used	Intervention duration; number of sessions (min/session)	Type of intervention	Intervention provider	Settings	Outcome measures
1	Askari et al (2018) [72]	Randomised clinical trial	Iran	Lower middle income	108 (I: 54, C: 54)	12	I: 66.45 (3.40); C: 67.11 (3.25)	Face to face and telephone follow up	Group session	BASNEF model	12 weeks; 8 (70)	Lifestyle modification (focus on diet and exercise)	Researcher	Diabetes centre	HbA1c, FBS, TG, LDL, HDL
2	Azami et al (2018) [93]	Randomised control trial	Malaysia	Upper middle income	142 (I: 71, C: 71)	39	54.2 (11.8)	Face to face and telephone follow up	Group session	Nurse led DSME (diabetes self-management education)	12 weeks; 4 (120)	DSME intervention	Nurse	Urban primary and secondary outpatient endocrine clinic within a teaching hospital	HbA1c, TG, HDL, LDL, SBP, DBP, BMI, quality of life, self-efficacy
3	Baviskar et al (2021), [1]	Randomised control trial	India	Lower middle income	80 (I: 40, C: 40)	26	NR	Face to face	Group session	Self-care and diabetes realted educational intervention	24 weeks; NR	DSME intervention	Investigator and Medical Social worker	Malavni Urban Health Training Centre	HbA1c, FBG, BMI, Quality of Life
4	Chow et al (2016) [51]	Non-clinical randomised controlled trial	Malaysia	Upper middle income	150 (I:75, C:75)	26	NR	Face to face and telephone reminder	Individual session	Home-based educational intervention	24 weeks; 2 (62)	DSME intervention	Pharmacist	Home based	HbA1c, diabetes knowledge
5	Debussche et al (2018) [91]	Randomised control trial	Mali	Low income	151 (I: 76 C: 75)	52	I: 53.9 (9.8); C: 51.1 (9.6)	Face to face	Group and individual session	Self-management educational intervention	52 weeks; 4 (120)	DSME intervention	Peer educators	Community	HbA1c, BMI, SBP, DBP, WC, diabetes Knowledge
6	Didarloo et al (2016) [73]	Randomised control trial	Iran	Lower middle income	90 (I: 45, C:45)	12	NR	Face to face	Group session	Collaborative and interactive teaching methods	12 weeks; 4 (60)	DSME intervention	Nurse	Diabetes clinic	HbA1c, Quality of Life
7	Ebrahimi et al (2016) [74]	Double blind Randomised clinical trial	Iran	Lower middle income	106 (I:53, C:53)	8	I: 46.97 (5.54); C:48.15 (6.52)	Face to face	Group session	Empowerment approach training	8 weeks; 5 to 7 (60 to 90)	DSME intervention	Nurse, endocrinologist and nutritionist	Diabetes center	HbA1c
8	Essien et al (2017) [75]	Individually-randomised controlled trial	Nigeria	Lower middle income	158 (I: 59, C:59)	26	All: 52.7; I:52.6; C: 52.8	Face to face and Mobile phone messages	Group session	Diet, nutrition and medication related education	26 weeks; 6 (60)	DSME intervention	Physician and nurse	Endocrinology clinic, Teaching Hospital	HbA1c, SBP, DBP, BMI
9	Gathu et al (2018) [76]	Non-blinded randomised clinical trial	Kenya	Lower middle income	140 (I:70, C:70)	26	All: 48.8 (9.8); (I: 50.2 (9.93); C: 47.5 (9.54)	Face to face and telephone reminders	Group session	Diabetes self-management education and support (DSMES): an empowerment and interactive teaching model	24 weeks; 6 (60)	DSME intervention	Family physician and diabetes educator	Family medicine clinic (private, urban-based) of a university hospital	HbA1c, SBP, DBP, BMI
10	Goldhaber-Fiebert et al (2003) [52]	Randomised control trial	Vietnam	Upper middle income	75 (I:40, C:35)	12	I: 60 (10); C: 57 (9)	Face to face	Group session	Community-based nutrition and exercise intervention	12 weeks; 11 (90)	Lifestyle modification (focus on diet and exercise)	Physician	Community centres	HbA1c, FBG, BMI, SBP, DBP, TC, HDLc, LDLc, TG
11	Goodarzi et al (2012) [77]	Randomised control trial	Iran	Lower middle income	100 (I:50, C:50)	12	I: 50.98 (10.32); C: 56.71 (9.77)	Text message	Individual session	Distance education via mobile phone text messaging	12 weeks; 48 (messages)	DSME intervention	Researcher	Hospital	HBA1c, TC, HDL, LDLc,TG, Knowledge, self-efficacy
12	Grillo et al (2016) [53]	Single-center, parallel-group, randomised study	Brazil	Upper middle income	131 (I: 69, C:62)	54	I: 61.7 (9.9); C: 63.2 (9.7)	Face to face	Group session	Education on diabetes care	7 weeks; 7 (120)	DSME intervention	Nurse	Primary care unit	HbA1c, BMI, WC, SBP, DBP, TC, LDL, HDL, TG
13	Hosseini et al (2017) [78]	Randomised control trial	Iran	Lower middle income	106 (I:53, C: 53)	26	I: 51.55 (8.3); C: 58.09 (1.6)	Face to face	Group session	PRECEDE model	4 weeks; 4 (120)	DSME intervention	General physician and specialist in health education and promotion	Diabetes clinic	HbA1c, BMI

(Continued)

Table 1. (Continued)

Sl No	First author (year)	Study design	Country	Country by income	Sample size	Study duration (in weeks)	Age in years Mean (SD)	Mode of delivery of the intervention	Intervention format	Model/theory used	Intervention duration; number of sessions (min/session)	Type of intervention	Intervention provider	Settings	Outcome measures
14	Huo et al (2019) [55]	Randomised clinical trial	China	Upper middle income	502 (I: 251, C: 251)	26	All: 59.5	Text message	Individual session	A text messaging–based secondary prevention program with the regular automatic delivery of text messages.	26 weeks; 156 (text messages)	DSME intervention	Text messages	Hospital	HbA1c, FBG, SBP, LDL, BMI
15	Jain et al (2018) [79]	Open-label randomised controlled trial	India	Lower middle income	299 (I: 153, C:146)	24	I: 55.69 (10.94); C:57.42 (10.95)	Face to face and telephone reminder	Individual session	Combining face-to-face interaction with telephonic reminders by community health workers	24 weeks; 4 (home visits)	DSME intervention	Community health workers	Tertiary teaching institute	HbA1c, FBS, SBP, DBP, BMI, WC, TC, TG, LDL C, HDL
16	Jayasuria et al, (2015) [80]	Randomised control trial	Sri Lanka	Lower middle income	87 (I: 43, C: 42)	26	All: 51.4 (7.2)	Face to face	Group and individual session	Diabetes Self-Management-Sri Lanka (DSM-SL) model	26 weeks; 9 (60)	Lifestyle modification (diet and exercise)	Physician and nurse	Colombo North Teaching Hospital	HbA1c, SBP, TC, LDL, HDL, BMI, self-efficacy
17	Jiang et al (2019) [56]	Multicentre randomised controlled trial	China	Upper middle income	265 (I: 133, C: 132)	26	All: 56.91 (10.05)	Face to face	Group session	Structured education programme Self-Efficacy for Diabetes (C-SED) Diabetes Distress Scale (C-DDS) Summary of Diabetes Self Care Activities (C-SDSCA)	26 weeks; 4 (60 to 90)	DSME intervention	Physician and nurse	Multicentre at Bejing, Fujiam, Jiangxi	HbA1c, WC, BMI, blood pressure, TC, TG, LDL, HDL, diabetes knowledge, self-efficacy
18	Ju et al (2018) [57]	Cluster randomised control trial	China	Upper middle income	400 (I:200, C:200)	52	I: 67.8 (7.4); C: 68.8 (8)	Face to face	Group session	A community based peer support programe	52 weeks; 12 (120)	DSME intervention	Peer support/ Leaders	Eight community health centres	HBA1c, FBG
19	Kong et al (2019) [58]	Group Randomized Experimental Study	China	Upper middle income	278 (I: 142, C: 136)	39	I:69.12 (10.54); C: 71.48 (8.79)	Face to face	Group session	Chronic Care Model	39 weeks; 9 (NR)	DSME intervention	Physician, health manager and public health assistant	Community health service center	HbA1c, SBP, DBP, BMI, TC, LDL, HDL
20	Lamptey et al (2023) [38]	Single-blind randomised parallel comparator controlled multi-centre trial	Ghana	Lower middle income	206 (I:103; C:103)	13	I: 59; C: 57	Face to face	Group session	DESMOND: EXTENDing availability of self-management structured education programmes	13 weeks; 1 (720)	DSME intervention	Educator	Hospitals	HbA1c, WC, SBP, DBP, PAID
21	Li et al (2016) [59]	Randomized controlled trial	China	Upper middle income	196 (I: 98, C: 98)	4	I:59.1 (4.6); C: 58.3 (4.1)	Face to face	Group session	Structured diet and/ or exercise program (SDEP)	4 weeks; NR (NR)	DSME intervention	Health educators, doctors, and nutritionists	Hospital	HbA1c, FPG, BMI, TG, TC, HDL, LDL
22	Lou et al (2020) [60]	Randomised control trial	China	Upper middle income	1095 (I: 563, C: 532)	104	66.5 (8.7)	Face to face	Group session	Clinic-based intensified diabetes management model (C-IDM)	GPs and nurses: 24 weeks; NR (NR) Patients with diabetes: 78 weeks; 18 (NR)	DSME intervention	Not stated	Disease control centers, general hospitals and local clinics	HbA1c, FBG, SBP, DBP, BMI, TG, TC, HDL, LDL
23	Mohammadi et al (2018) [81]	A matched-pair design randomized controlled trial	Iran	Lower middle income	240 (I: 120, C: 120)	48	I: 51.2 (6.2); C: 51.4 (6.1)	Face to face	Group session	Health Belief Model (HBM)	12 weeks; 8 (120)	DSME intervention	Not stated	Golestan Hospital outpatient diabetes clinic	HbA1c, FBS, BMI, TC, TG, LDL, HDL, nutrition knowledge, quality of life, self-efficacy

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Table 1. (Continued)

Sl No	First author (year)	Study design	Country	Country by income	Sample size	Study duration (in weeks)	Age in years Mean (SD)	Mode of delivery of the intervention	Intervention format	Model/theory used	Intervention duration; number of sessions (min/session)	Type of intervention	Intervention provider	Settings	Outcome measures
24	Muchiri et al (2016) [61]	Randomised control trial	South Africa	Upper middle income	82 (I:41, C:41)	52	I:59.4 (6.9); C:58.2 (8.0)	Face to face	Group session	Nutrition education	52 weeks; 8 (120 to 180) and follow-up 6 (90)	DSME intervention	Health professionals	Community health centres	HbA1c, FBS, BMI, TC, TG, LDL, HDL
25	Myers et al (2017) [82]	Cluster randomised control trial	India	Lower middle income	239 (I:85, C:154)	52	46.3 (9.5)	Face to face	Group session	Nutrition practice guidelines	24 weeks; NR (NR)	Lifestyle modification (focus on diet)	Dietitian	Diabetes centres hospitals	HbA1c, BMI, TC, LDL, HDL, TG
26	Mash et al (2014) [62]	Pragmatic clustered randomized controlled trial	South Africa	Upper middle income	1570 (I:710, C:860)	52	I:55.8 (11.5); C:56.4 (11.6)	Face to face	Group session	Diabetes education programme	30 weeks; 4 (60)	DSME intervention	Educator	Community health centres	HbA1c, SBP, DBP, WC, TC, self-efficacy
27	Ojieabu et al (2017) [83]	Randomised control trial	Nigeria	Lower middle income	150 (I:75, C:75)	17		Face to face	Group session	Intervention of medication and treatment adherence	17 weeks; 4 (NR)	DSME intervention	Pharmacist	Endocrinology Clinic, Teaching Hospital	FBS, BMI, SBP, DBP
28	Ramadas et al (2018) [63]	Multi-centre randomised control trial	Malaysia	Upper middle income	128 (I:66, C:62)	104	I:49.6 (10.7); C:51.5 (10.3)	Web based	Web session	Malaysian Dietary Intervention for People with Type 2 Diabetes: An e-Approach (myDIDeA)	26 weeks; 12 (12)	Lifestyle modification (focus on diet)	Nutritionist	Public hospital	HbA1c, FBG, diabetes knowledge
29	Ramli et al (2016) [64]	Pragmatic cluster randomised controlled trial	Malaysia	Upper middle income	888 (I:471, C:417)	104	I:58 (0.48); C:57 (0.5)	Face to face	Group session	EMPOWER-PAR (Participatory action research) interventions	52 weeks; 2 (NR)	DSME intervention	Physician, nurse, pharmacist and dietitian/nutritionist	Public primary care clinics	HbA1c, BMI, SBP, DBP, WC, TC, TG, LDL, HDL
30	Samtia et al (2013) [84]	Randomized study	Pakistan	Lower middle income	344 (I:174, C:170)	20	I:46.1; C:42.3	Face to face	Group session	Intervention regarding disease knowledge and self-care	20 weeks; NR (NR)	DSME intervention	Physician and pharmacist	Diabetes clinic at hospital	HbA1c, FBS, BMI
31	Sanaeinasab et al (2021) [85]	Randomised controlled trial	Iran	Lower middle income	80 (I:40, C:40)	30	All: 50.7 (5.9)	Face to face	Group session	Comprehensive systematic health education and promotion (SHEP) model	7 weeks; 6 (90)	DSME intervention	Not stated	Diabetic clinics	HBA1c, FBG, BMI, SBP, DBP, TC, HDL, LDL, TG
32	Salahshouri (2018) [86]	Randomised control trial	Iran	Lower middle income	145 (I:73; C:72)	26	I:55.93 (12.4); C:54.53 (9.43)	Face to face	Group session	Intervention based on psychological factors and nutrition	NR weeks; 8 (60)	Lifestyle modification (focus on diet)	Internal specialists, dietitians, diabetes experts, a psychologist, as well as a religious expert	Diabetic clinics and healthcare centres	HbA1c, FBS, self-efficacy
33	Tan et al (2011) [65]	Single-blind randomised control trial	Malaysia	Upper middle income	164 (I:82, C:82)	12	I:54 (9.94); C:54 (10.74)	Face to face and telephone follow up	Group session	Self-efficacy theory	12 weeks; 3 (45)	DSME intervention	Not stated	Govt state hospital	HbA1c, diabetes knowledge, self-efficacy
34	Thanh et al (2021) [87]	Randomised controlled single-center trial	Vietnam	Lower middle income	364 (I:182, C:182)	52	All: 62.2 (9.3)	Face to face	Group session	Education on diet, exercise, drug therapy and adherence	12 weeks; 3 (45)	DSME intervention	Medical staff educators	Diabetes clinic	HbA1c, FBG, SBP
35	Wattana et al (2007) [66]	Randomised controlled trial	Thailand	Upper middle income	147 (I:75, C:72)	26	I:58.40 (10.05); C:55.14 (10.22)	Face to face	Group and individual session	Diabetes self-efficacy and diabetes self-management program	24 weeks; 5 (90 to 120) and one-off 2 home visits (45)	DSME intervention	Physician and researcher	Diabetic clinics	HbA1c, HrQol

(Continued)

Table 1. (Continued)

SI No	First author (year)	Study design	Country	Country by income	Sample size	Study duration (in weeks)	Age in years Mean (SD)	Mode of delivery of the intervention	Intervention format	Model/theory used	Intervention duration; number of sessions (min/session)	Type of intervention	Intervention provider	Settings	Outcome measures
36	Whittemore et al (2020) [67]	Randomised control trial	Mexico	Upper middle income	47 (I: 26, C: 21)	52	55.35 (8.75)	Face to face and follow up by phone calls	Group session	Si Yo Puedo DSME program	52 weeks; 7 (NR) and phone call every 2 weeks and text/picture messages sent daily for 6 months	DSME intervention	Nurse and social worker	Seguro Popular clinics	HbA1c, BMI, SBP, DBP, self-efficacy
37	Wichit et al (2017) [68]	Randomised controlled trial	Thailand	Upper middle income	140 (I:70, C:70)	13	I: 61.3 (11.6); C: 55.5 (10.5)	Face to face, home visit and telephone follow up	Group session	Self-efficacy theory	9 weeks; 3 (120)	DSME intervention	Nurse	Hospital	HbA1c, diabetes knowledge, HrQoL
38	Yan et al (2014) [92]	Randomised study	Mozambique	Low income	41(I: 31, C: 10)	12	I: 53 (2); C: 55 (3)	Face to face	Group session	Exercise training intervention	12 weeks; 36 to 60 (45)	Lifestyle modification (focus on exercise)	Not stated	Diabetes clinic	HbA1c, BMI, WC, SBP, DBP
39	Zhang et al (2018) [69]	Randomised study	China	Upper middle income	998 (I:498, C: 500)	348	I: 50.8 (14.3); C: 52.6 (13.2)	Face to face	Group and individual session	Intervention on nutrition therapy, individualized exercise program, screening of complications	104 weeks; 24 (NR)	DSME intervention	Physician	Hospital	HbA1c, BMI, SBP, DBP, TC, HDL, LDL
40	Zheng et al (2019) [70]	Randomised controlled trial	China	Upper middle income	60 (I: 30, C:30)	104	52.22 (11.32)	Face to face	Group session	Diabetes self-management education programme	104 weeks; 2 (45)	DSME intervention	Therapist guidance	Hospital	HbA1c, FBG
41	Zhong et al (2015) [71]	Randomised study	China	Upper middle income	726 (I: 365; C: 361)	64		Face to face	Group session	Peer leader–support program for diabetes management	24 weeks; 12 (120)	DSME intervention	Peer leaders and staff of Community Health Service Centers (CHSCs)	Community	FBS, BMI, SBP, DBP, diabetes knowledge, self-efficacy
42	Al-Halaweh et al (2019) [88]	Quasi-experimental study	Palestine	Lower middle income	200 (I: 100; C: 100)	52	I: 56.58 (8.76); C: 57.9 (7.79)	Face to face	Group and individual session	Diabetes comprehensive care model (DCCM)	52 weeks; 4 (NR)	DSME intervention	Team of internal specialists, dietitians, diabetes experts, psychologist, and religious expert	Mobile diabetes clinic	Wt, Ht, BP, HbA1c, TC, Creatinine, Microalbuminuria
43	Pamungkas et al (2020) [89]	Quasi-experimental research	Indonesia	Lower middle income	60 (I: 30; C:30)	12	I: 56.5 (7.63); C: 54.2 (9.20)	Face to face	Group session	The diabetes mellitus self-management (DMSM) based coaching program	12 weeks; 3 (NR) and 1 (home visit)	DSME intervention	Researcher	Public health centers	HbA1c, SBP, DBP, BMI, TC, HDL, LDL
44	Kumari et al (2018) [90]	Quasi-experimental prospetive trial	India	Lower middle income	202 (I:102; C: 100)	65	I: 51.9 (9.3); C: 54 (8.6)	Face to face	Group and individual session	Lifestyle intervention holistic model (LIHM)	52 weeks; 6 (10 to 15)	Lifestyle modification (focus on diet)	Dietician, diabetes educator, physical trainer and diabetologist	Delhi Diabetes Research Centre	HbA1c, blood sugar fasting, blood sugar postprandial

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[1, 51–53, 55–57, 59, 61, 62, 69–71, 73, 75, 77, 79, 82–84, 86, 87, 92] cited no theoretical framework or model used to inform the intervention designs.

Approximately 73% (n = 32) of the interventions were delivered using a face-to-face format, 20% (n = 9) utilising face-to-face intervention with telephone follow-up and 7% (n = 3) using a remotely delivered text message/web-based intervention. Intervention was delivered by healthcare professionals (e.g. physician, nurse, pharmacist, health educator, dietitian or nutritionist) in 32 trials [1, 38, 51–54, 56, 58, 59, 61–64, 66–70, 73–76, 78–80, 82–84, 86–88, 90], by the research team in three trials [72, 77, 89], by peer leaders or lay facilitators in three trials [57, 71, 91] and by trained educators in one trial [62]. Five trials did not report the type of intervention facilitator [60, 65, 81, 85, 92]. The intervention formats included groups (n = 33 [75%]), individuals (n = 4 [9%]), a combination of groups and individuals (n = 6 [14%]) and web-based (n = 1 [2%]) intervention strategies.

Effect of DSME intervention on HbA1c and FBG control

Of 41 RCT studies, 39 reported HbA1c (n = 10,500 participants). Upon meta-analysis, intervention significantly lowered HbA1c levels compared to the control, with a MD of 0.64% (95% CI: 0.64% to 0.83%; p = 0.001). Heterogeneity was very high between the studies (I^2 = 94%) with no publication bias (Egger's regression test, p = 0.068) (Fig 2 and Table 2).
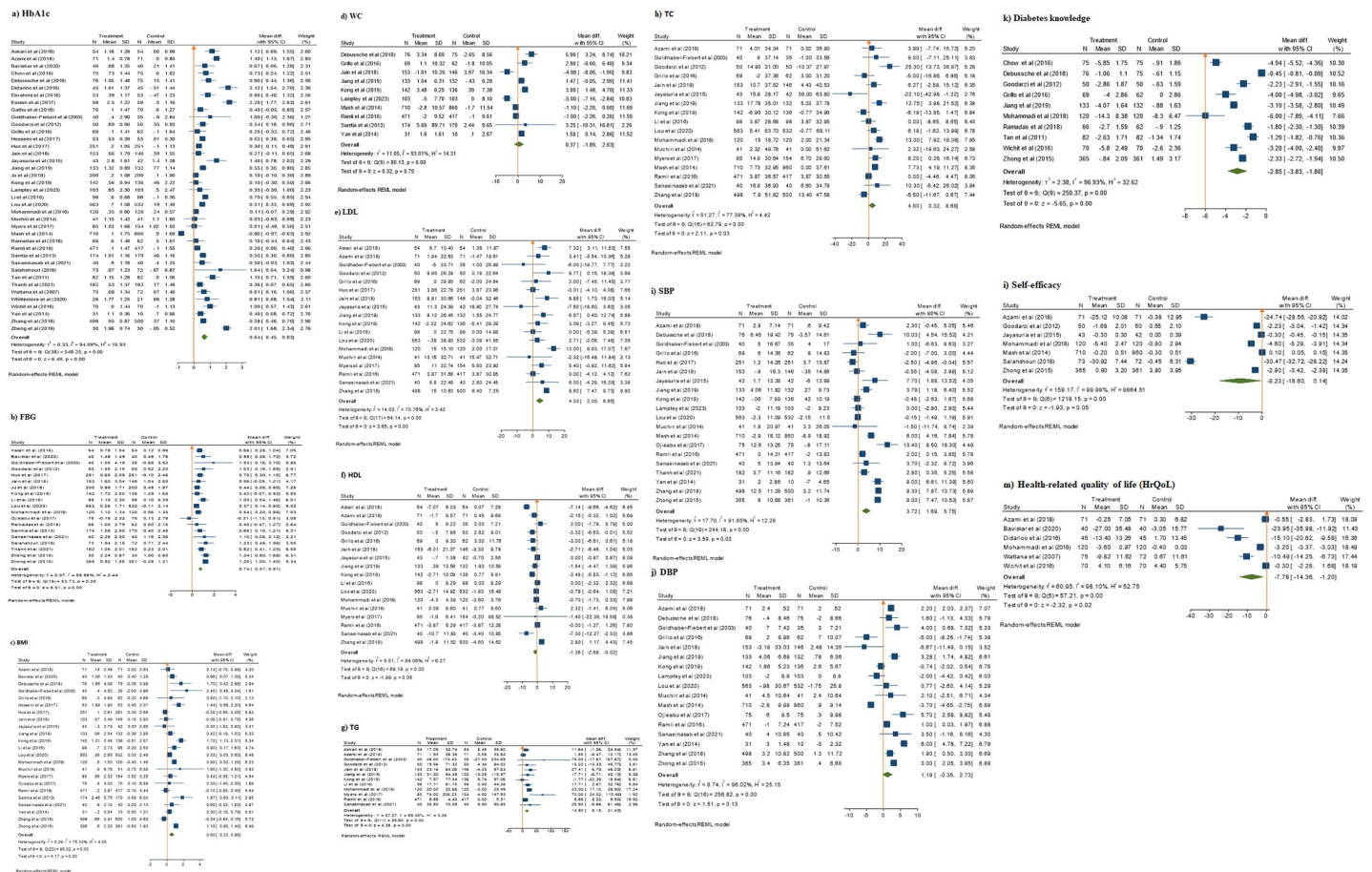

Fig 2. Meta-analysis results showing the effect of DSME interventions on clinical outcomes (a) HBA1c (b) FBG (c) BMI (d) WC (e) LDL (f) HDL (g) TG (h) TC (i) SBP (j) DBP, (k) diabetes knowledge, (l) self-efficacy, and (m) health-related quality of life of RCTs studies [Data are reported as mean difference (95% confidence limits)].

Table 2. Summary results.

Study design	Outcome types	Measures	n	Mean change difference (with 95% CI), p-value	Effect of intervention	Heterogeneity (I^2 in %)	Publication bias (Egger's regression test p)
RCTs	Clinical	HbA1c	39	0.64 (0.45, 0.83), 0.001	Effective	94	0.0680
		FBG	19	0.74 (0.57, 0.91), 0.001	Effective	5996	0.5927
	Metabolic risk factors	BMI	23	0.60 (0.32, 0.88), 0.001	Effective	75	0.1738
		WC	10	0.37 (-1.89, 2.63), 0.001	Effective	93.01	0.6884
		LDL	18	4.33 (2.33–6.65), 0.001	Effective	71	0.0758
		HDL*	17	-1.35 (-2.69, 0.02), 0.05	Effective	84.06	0.2715
		TC	17	4.50 (0.32, 8.68), 0.03	Effective	779	0.5804
		TG	12	14.80 (8.18, 21.43), 0.001	Effective	69	0.0535
		SBP	20	3.72 (1.69, 5.75), 0.001	Effective	92	0.8676
		DBP	17	1.19 (-0.35, 2.73), 0.13	Effective	96	0.5148
	Diabetes self-managemnt behaviours	Diabetes knowledge*	10	-2.85 (-3.83, -1.79), 0.001	Effective	97	0.0070
		Self-efficacy*	7	-9.23 (-18.60, 0.14), 0.001	Effective	99	0.0001
	Psychosocial	HrQoL*	6	-7.78 (-14.36, -1.20), 0.02	Effective	98	0.0005
Quasi-experimental design study	Clinical	HbA1c	3	1.27 (-0.63, 3.17), 0.19	Effective	97	0.4515

*Negative results consider the positive effect of the intervention

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Among 19 studies (n = 5,370 patients) that reported FBG, an overall decrease by 0.74 mmol/L (95% CI: 0.57% to 0.91%; p < 0.001) was observed in the intervention as compared with the control, with moderate heterogeneity (I^2 = 59%) and no publication bias (Egger's regression test, p = 0.592) (Table 2).

In trials with quasi-experimental designs, the findings showed a mean reduction in HbA1c of 1.27% (95% CI: -0.63% to 3.17%; p = 0.19) in the intervention as compared to the control (Fig 3). The I^2 indicator was 97%, indicating a high heterogeneity with no publication bias (Egger's regression test, p = 0.451) (Table 2). These studies did not report FBG levels.

Effect of DSME interventions on cardiometabolic risk factors

DSME intervention reduced BMI by 0.60 kg/m^2 (95% CI: 0.32% to 0.88%; p = 0.001, I^2 = 75.33%) in 23 studies comprising 7,253 participants (Fig 2). Similarly, the results presented in
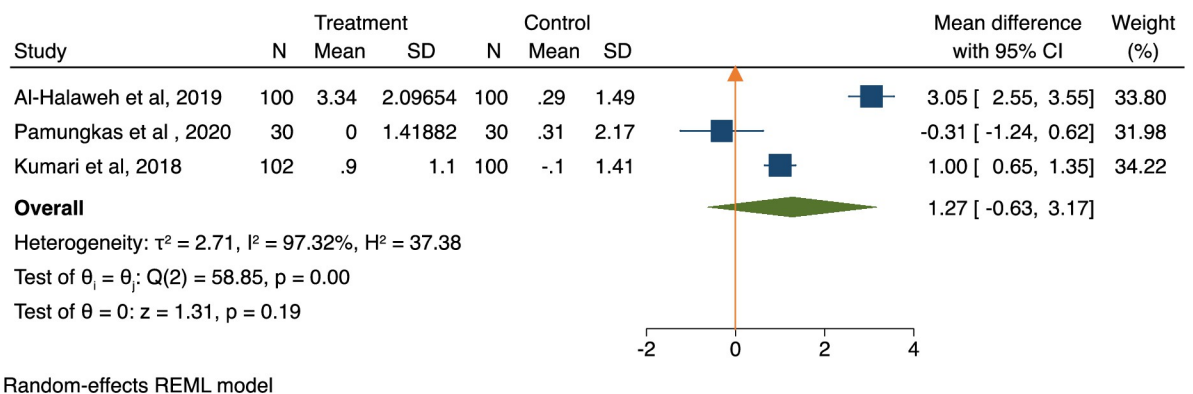
Fig 3. Meta-analysis results showing the effect of DSME interventions on glycaemic control (HbA1c) of quasi-experimental studies.

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Table 2 and forest plots showed a positive intervention effect on all cardiometabolic risk factors: WC (n = 4,173, MD 0.37, 95% CI: -1.89% to 2.63%; p = 0.001, I^2 = 93%), LDL (n = 5803, MD 4.33, 95% CI: 2.33% to 6.65%; p = 0.001, I^2 = 71%), HDL (n = 5301, MD -1.35, 95% CI: -2.69% to -0.02%; p = 0.05, I^2 = 84.06%), TG (n = 6763, MD 14.80. 95% CI: 8.18% to 21.43%; p < 0.001, I^2 = 69%), TC (n = 6,763, MD 4.50, 95% CI: 0.32% to 8.68%; p = 0.03, I^2 = 779%), SBP (n = 8,128 MD 3.93, 95% CI: 1.83% to 6.04%; p <0.001, I^2 = 926%) and DBP (n = 7,177, MD 1.19, 95% CI: -0.35% to 2.73%; p = 0.13, I^2 = 96%). Moderate-to-high heterogeneity was observed across all forest-plot analyses of cardiometabolic risk factors.

The effect of DSME intervention on diabetes knowledge, self-efficacy and HrQoL

Ten studies (n = 2,195) that evaluated knowledge of diabetes showed an improvement by MD of -2.85 (95% CI: -3.83% to -1.86%; p<0.001, I^2 = 97%) with presence of publication bias (Egger's regression test, p = 0. 0.007) (Fig 2). Impact on self-efficacy was addressed in seven studies (n = 1,588), showing an increase by 9.23 (95% CI: -18.60% to 0.14%; p = 0.05, I^2 = 99%) with presence of publication bias (Egger's regression test, p = 0.0070) (Fig 2). Six trials (n = 839) that reported HrQoL showed improvement by -7.78 (95% CI: -14.36% to –1.20%; p = 0·02, I^2 = 98%). Publication bias was present in these studies (Egger's regression test, p = 0.0005) (Fig 2).

Subgroup/Sensitivity analysis

Moderate-to-high heterogeneity was observed across the studies regarding primary as well as secondary outcomes. In order to identify the sources of heterogeneity, subgroup/sensitivity analysis was conducted for the DSME intervention by the income level of the country, intervention type, mode of delivery of intervention and quality of the studies. As outlined in S1 Fig, DSME intervention showed that lower-middle-income countries had improvement in HbA1c with a MD of 0.75% (95% CI: 0.45% to 1.06%; p<0.001, I^2 = 92%). Further, lifestyle modification (i.e. diet and/or exercise) intervention showed a greater effect on HbA1c reduction (MD: 0.69%, 95% 0.22% to 1.16%; p<0.001, I^2 = 78%) than DSME interventions (MD: 0.63%, 95% CI: 0.42 to 0.86; p<0.001, I^2 = 95%) (Table 3 and S2 Fig). In addition, subgroup analysis by mode of delivery of intervention showed that face-to-face intervention with periodic telephone follow-up had the highest efficacy on HbA1c reduction (MD: 1.02%, 95% CI: 0.63% to 1.40%; p<0.001, I^2 = 86%) followed by face-to-face intervention alone (MD: 0.56%, 95% CI:0.32% to 0.80%; p<0.001, I^2 = 95%) and text message or web-based intervention (MD: 0.33%, 95% CI: 0.17% to 0.49%; p = 0.35, I^2 = 0.00) (Table 3 and S3 Fig). The quality of the trials with some concerns showed (S4 Fig) reduction in HbA1c with a MD of 0.66% (95% CI: 0.41% to 0.90%, p<0.001, I^2 = 93%) compared with trails rated as high or weak. The S1–S4 Figs present subgroup analyses for BMI and lipid profiles (LDL, HDL, TG and TC) by the income level of the country, intervention type, mode of delivery of the intervention and quality of the study. In studies from low-income countries (MD: 0.87, 95% CI: -0.48% to 2.22%; p = 0.05, I^2 = 75%), DSME intervention (MD: 0.63, 95% CI: 0.31% to 0.94%; p<0.001, I^2 = 78%), face-to-face intervention (MD: 0.71, 95% CI: 0.41% to 1.01%; p<0.001, I^2 = 74%) and trials evaluated as high risk (MD: 0.68, 95% CI: 0.18% to 1.18%, p<0.001; I^2 = 82%) showed a better BMI reduction. Further, studies conducted in lower-middle income countries presented an improvement in LDL (MD: 7.32%, CI: 3.50% to 11.15%; p = 0.05, I^2 = 56%), HDL (MD: -3.12, 95% CI: -5.62% to -0.62%; p<0.001, I^2 = 89%), TC (MD:8.72, 95% CI: 0.88% to 18.32%; p<0.001, I^2 = 83%) and TG (MD: 21.73, 95% CI: 15.26% to 28.19%; p<0.19, I^2 = 10.66%).

Table 3. Subgroup analysis, based on the income level of the country, intervention type, mode of delivery of the intervention, and quality of the studies.

Subgroup	HbA1c	BMI	LDL	HDL	TG	TC
Income level of the country						
Low income	MD: 0.62 (0.13–1.11), I^2 67%	MD: 0.87 (-0.48–2.22), I^2 75%	N/A	N/A	N/A	N/A
Lower middle income	MD: 0.75 (0.45–1.06), I^2 92%	MD: 0.69 (0.32–1.06), I^2 46%	MD: 7.32 (3.50–11.15), I^2 56%	MD: -3.12 (-5.62––0.62), I^2 88%	MD: 21.73 (15.26–28.19), I^2 10%	MD: 8.72 (-0.88–18.32), I^2 83%
Upper middle income	MD: 0.55 (0.28–0.83), I^2 94%	MD: 0.53 (0.10–0.96), I^2 83%	MD: 2.78 (0.20–6.65), I^2 71%	MD: -0.34 (-1.69–1.00), I^2 69	MD: 8.85 (8.21–9.48), I^2 0.00%	MD: 2.05 (-1.99–6.09), I^2 660%
Intervention type						
Lifestyle modifications (diet and/or exercise)	MD: 0.69 (0.22–1.16), I^2 78%	MD:0.35 (-0.03–0.74), I^2 0.00%	MD:1.63 (-5.58–8.84), I^2 716%	MD: -1.77 (-6.75–3.22), I^2 91%	MD:42.24 (-4.21–88.70), I^2 70%	MD: 0.11 (-17.99–18.22), I^2 78%
Self-management	MD: 0.63 (0.42–0.85), I^2 95%	MD:0.63 (0.31–0.94), I^2 78%	MD: 4.33 (2.00–6.65), I^2 71%	MD: -1.14 (-2.38–0.11), I^2 74%	MD:13.64 (6.52–20.77), I^2 69%	MD: 4.86 (0.38–9.35), I^2 77%
Mode of delivery of the intervention						
Face-to-face	MD: 0.55 (0.32–0.78), I^2 94%	MD: 0.71 (0.41–1.01), I^2 74%	MD: 3.77 (0.77–6.77), I^2 75%	MD: -0.50 (-1.68–0.68), I^2 76%	MD: 16.93 (8.19–25.68), I^2 74%	MD: 3.15 (-1.08–7.39), I^2 754%
Face-to-face and telephone follow up	MD: 1.02 (0.63–1.40), I^2 86%	MD: 0.03 (0.56–0.62), I^2 0.00%	MD: 6.79 (3.58–10.01), I^2 0.00%	MD: -4.18 (-7.46–-0.89), I^2 70%	MD: 11.30 (-1.79–24.39), I^2 62%	MD: 5.44 (-1.62–12.51), I^2 0.00%
Text messages or web-based	MD: 0.33 (0.17–0.49), I^2 0.00%	MD: -0.20 (-0.65–0.25), I^2 N/A*	MD: 3.87 (-5.51–13.25). I^2 708%	MD: -3.32 (-6.63–0.0.01), I^2.%N/A*	MD: 15.22 (-15.33–45.77), I^2.% N/A*	MD: 25.30 (13.73–36.87), $I^{2.\%}$ NA*
Quality of the studies						
High	MD: 0.60 (0.30–0.91), I^2 94%	MD: 0.68 (0.18–1.18), I^2 82%	MD: 5.40 (-2.26–8.55), I^2 60%	MD: -1.87 (-5.09–1.34), I^2 92%	MD:-2.36 (-10.13–5.42), I^2 71%*	MD: -2.36 (-10.13–5.42), I^2 71%
Some concerns	MD: 0.66 (0.41–0.90), I^2 94%	MD: 0.49 (0.19–0.78), I^2 75%	MD: 3.94 (0.79–7.09), I^2 71%	MD: -0.69(-1.31–0.07), I^2 84%	MD: 7.26 (3.00–11.52), I^2 70%	MD: 7.26 (-3.00–11.52), I^2 70%

*N/A = not applicable, as $\leq$ one study in analysis.

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In addition, intervention focused on DSME intervention demonstrated the highest MDs in LDL and TC (LDL: MD 4.33, 95% CI: 2.00% to 6.65%; p<0.001, I^2 71; and TC: MD 4.86 95% CI: 0.38% to 9.35%; p<0.001, I^2 77%) (Table 3). Lifestyle modification intervention alone showed better efficacy in reducing HDL (MD: -1.77, 95% CI: -6.75% to 3.22%; p<0.001, I^2 = 91%) and TG (MD 42.24, 95% CI: -4.21 to 88.70; p<0.001, I^2 70%) (Table 3). Furthermore, face-to-face intervention with periodic telephone follow-up showed the highest MDs in LDL (MD 6.79, 95% CI: 3.58% to 10.01%; p = 0.52, I^2 = 0.00%) and HDL (MD -4.18, 95% CI: -7.46% to -0.89%; p = 0.03, I^2 = 0.03%) (Table 3). However, face-to-face intervention alone was more effective at reducing TG (MD 16.93, 95% CI:8.19% to 25.68%; p<0.001, I^2 = 73.96%) (Table 3). Trials classified as high risk of bias showed improvement in the lipid profile of LDL (MD 5.40, 95% CI: -2.26% to 8.55%; p<0.010, I^2 = 59.58%), HDL (MD -1.87, 95% CI: -5.09% to 1.34%; p = 0.001, I^2 = 92%) and TG (MD 7.26, 95% CI: 3.00% to 11.52%; p = 0.001, I^2 = 77%) (Table 3).

Risk of bias in the included studies

The randomisation process for allocation was evaluated as low risk of bias in 16 studies [1, 30, 52–56, 61, 62, 65, 67, 68, 70, 73, 77, 85], and 13 studies measured as having some concerns of bias [51, 58–60, 63, 64, 75, 79–81, 84, 86, 87]. No trials were rated as low in all five components of the assessment tool. Deviations from the intended interventions were rated as high risk of bias in six studies [57, 69, 72, 82–84]. The risk of bias was rated as some concerns due to missing outcome data in seven studies [51, 59, 71, 76, 77, 85, 93]. Regarding measurement of the outcome reporting, eight studies [54, 69–72, 80, 81, 85, 92] were apparent as high risk of bias.
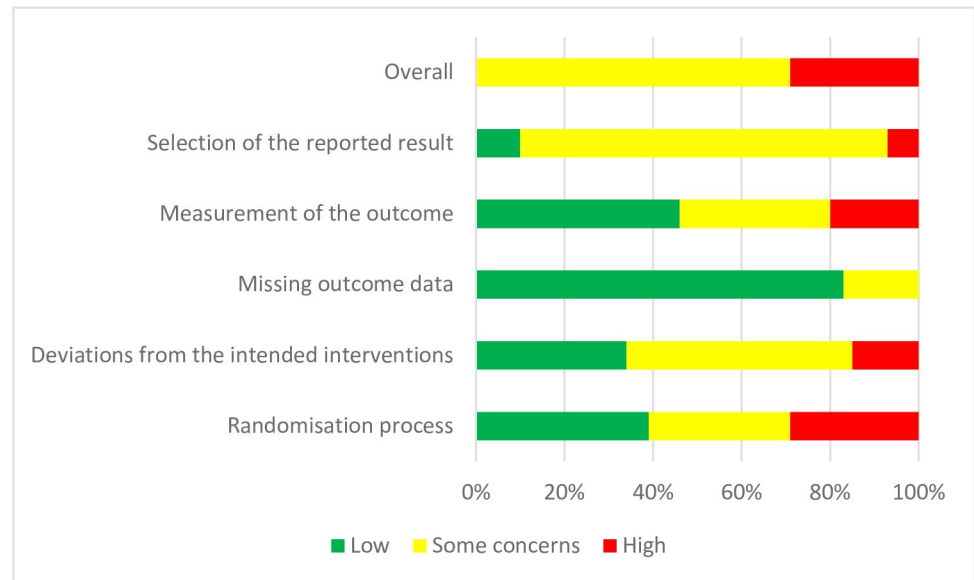
Fig 4. Risk of bias graph: Review authors' judgements about each risk of bias item presented as percentages across all included studies.

However, for the selection of the reported results, four studies were evaluated as low risk of bias [53, 74, 86, 91], and three studies were assessed as high risk of bias [58, 75, 93]. The overall risk of bias for studies is summarised in Fig 4 and the risk of bias in individual study is reported in S5 Fig.

A quality assessment was carried out for each of the quasi-experimental studies using the JBI Critical Appraisal Checklist [44, 89, 90]. However, the assessment was a subjective measure that was dependent on the author carrying out the assessment. As per the appraisal checklist, three studies [88–90] were considered and included in the meta-analysis. The details are shown in S6 Table.

Publication bias

The presence of publication bias for RCTs was visually assessed using a funnel plot for the primary outcome (HbA1c), which showed that there was no publication bias (Table 2). This was supported by the Egger's test ($p = 0.0680$). Publication bias was also assessed for the secondary outcomes and presented in the Table 2, which showed that there was no publication bias for FBG ($p = 0.5927$), BMI ($p = 0.1738$), WC ($p = 0.6884$), LDL ($p = 0.0758$), HDL ($p = 0.2715$), TC ($p = 0.5804$), TG ($p = 0.0535$), SBP ($p = 0.8676$) and DBP ($p = 0.5148$). Publication bias, however, was present for HrQoL ($p = 0.0005$), self-efficacy ($p < 0.001$) and diabetes knowledge ($p = 0.0070$). Regarding quasi-experimental studies, no publication bias was observed for HbA1c ($p = 0.4515$) (Table 2).

Overall quality of the evidence

The GRADE approach was employed to assess the overall quality of evidence, and the results are summarized in the main comparison's findings. Findings showed that the overall certainty of evidence for HDL and WC were moderate, which suggests further studies will increase our confidence in the estimate of effect size. The quality of the evidence for HbA1c, FBG, and BMI were low, which reflects that the effect size is limited and the true effect may be substantially

different from the estimate of the effect size. The quality of evidence for LDL, TC and TG were very low, which showed that the true effect is probably markedly different from the estimated effect (S7 Table).

Discussion

This systematic review and meta-analysis aimed to systematically examine the efficacy of DSME interventions on overall T2DM management and cardiometabolic outcomes. Pooled data were used covering 11,838 participants across 44 studies conducted in 21 LMICs. Comprehensive assessment was conducted to evaluate the effectiveness of DSME intervention on 13 outcomes measures including HbA1c control, cardiometabolic risk factors, self-efficacy, diabetes knowledge and psychosocial well-being factors among people with T2DM in LMICs. The outcomes were compared with those generated by standard care across both RCT and quasi-experimental trials. Consequently, a greater number of studies than the earlier reviews were included. This review and meta-analysis demonstrated that DSME intervention leads to better glycaemic control as compared to lifestyle modification intervention alone. Further, it also shows that face-to-face interventions followed by periodic phone calls results in better glycaemic control compared with only face-to-face or remote delivery strategies. The findings suggest that ongoing support is important in optimising intervention efficacy.

Compared with the standard care, this review showed that DSME intervention reduced HbA1c by 0.64% (95% CI: 0.45% to 0.83%) and 1.27% (95% CI: -0.63% to 3.17%) in RCTs and quasi-experimental design studies, respectively. This finding is consistent with previous reviews [20, 21, 93, 94] that reported a reduction in HbA1c levels by 0.83% (95% CI: 1.17% to 0.49%, n = 18 studies) [94] and 0.26% (95% CI: 0.05 to 0.48 n = 31 studies) [25] after DSME interventions. A decrease in HbA1c levels is known to reduce micro- and macro-vascular complications of people with T2DM in long-term follow-up [95–97]. Thus, DSME intervention should be a priority for optimising glycaemic control among people with T2DM in LMICs.

This review demonstrated that DSME intervention leads to significant improvement in FBG and other cardiometabolic risk factors (i.e. BMI, WC, SBP, DBP, LDL, HDL, TG and TC). The findings are in line with those of the previous review that showed the positive effects of group-based self-management education interventions on HbA1c, FBG, body weight, WC, TG and diabetes knowledge [98]. Another review, however, showed that there was no effect of community-based educational interventions on SBP and DBP [99]. Overall, these findings support the potential clinical, behavioural and psychological efficacy of DSME intervention in patients with T2DM.

Adults with diabetes or other metabolic diseases are more likely to have lower self-efficacy, knowledge about their illness and HrQoL [100] as compared with individuals without diabetes and metabolic syndrome. This meta-analysis showed that DSME intervention effectively increased self-efficacy, which is supported by a previous systematic review [101]. Additionally, in a tailored web-based intervention, patients with the highest self-efficacy had better outcomes; therefore, self-efficacy may play a moderating role in intervention outcomes and thus should be considered in tailoring DSME intervention for people with diabetes [102]. Peyrot and Rubin [103] found that those who had the worst self-care, improved the most following DSME intervention and that those with higher self-efficacy had a higher level of self-care behaviours. Self-efficacy provides the confidence necessary to overcoming disease barriers [104] and it receives the most consistent support as a strong determinant of diabetes self-care behaviours [105]. Further, in the present review, diabetes knowledge was significantly improved in the intervention group compared to controls (MD -2.85; 95% CI: -3.83% to -1.79%, p<0.001). Several meta-analyses have similarly shown that DSME interventions are

associated with significant improvements in knowledge of T2DM [94, 106, 107]. Our results also showed that DSME intervention leads to improvement in HrQoL, as reported previously [108]. Other reviews have also demonstrated that DSME and behavioural modification improve HrQoL, which in turn impacts self-care and patients' perceptions about diabetes care [109–112].

Subgroup analyses were performed by the income levels of the countries, intervention types, modes of delivery of the intervention, and quality of the studies. The analysis showed an overall improvement in HbA1c, BMI, LDL, HDL, TG and TC in the LMICs; however, low-income countries had a higher improvement in BMI (MD: 0.87, 95% CI: -0.48 to 2.22). It is possible that health-educational attainment has a direct impact on BMI. In addition, individuals with T2DM in low-income countries may be more physically active due to their need to secure income and also due to limited access to private transportation, leading to a less sedentary lifestyle as compared to those living in lower-middle-income countries [113]. In relation to intervention types, a noteworthy finding in this review is that people with T2DM who received DSME intervention had better BMI, LDL and TC reduction than those who received lifestyle (diet and physical activity) modification alone. This finding is similar to some [33, 34, 114] but not all [10] previous reviews reporting DSME intervention having a better effect on HbA1c control and BMI reduction. In addition to HbA1c and BMI, this current review demonstrated the efficacy of DSME interventions and lifestyle modification intervention in LDL, HDL, TG and TC. Another notable finding of this review is that the face-to-face interventions with periodic telephone follow-up results in better effects on glycaemic control and cardiometabolic risk than face-to-face or text message/web-based interventions alone, which is in line with the National Services Scheme by Diabetes Australia [115]. Periodic phone calls encouraging and reminding patients to practice self-management behaviours consistently over time improves their adherence to overall diabetes control [116]. Thus, face-to-face interventions with periodic telephone follow-up should be prioritised in future DSME intervention programmes for better T2DM management.

This systematic review and meta-analysis is noteworthy in terms of its synthesis of the evidence of outcomes through inclusion of trials using both RCTs and quasi-experimental intervention designs. Overall, it comprehensively summarises the potential clinical, behavioural and psychosocial efficacies of DSME interventions among people with T2DM in LMICs. In addition, five electronic databases were meticulously searched by the authors. As a result, a larger number of trials were identified leading to an impressive sample size of 11,838 participants. This review, however, has a few limitations. First, only a small number of studies were found from low-income countries. Second, the majority of the studies reported outcomes from less than one year follow-up, therefore the long-term effectiveness of DSME intervention in the management of T2DM population cannot be demonstrated. Third, high heterogeneity was observed in the meta-analyses for most of the outcome measures, which is likely due to variation in intervention programme design across the studies [99] as typically noted in intervention programmes of this nature. Fourth, no trial was categorised as low risk in all five components of the ROB 2 assessment tool. Particularly, randomisation process, deviations from the intended interventions, and measurement of the outcome were the most common risks of bias among the RCTs; hence, a prudent approach is warranted when interpreting the results of this present review. It is therefore recommended to follow the CONSORT statement [117] for parallel-group randomised trials to reduce the risk of biases when designing the methodology of the future RCTs. Further, the assessment of outcomes data was measured in heterogeneous ways in the included studies of this review and the certainty of evidence is not sufficient to assert the effectiveness of interventions among patients with T2DM. Hence, to enhance the

certainty of evidence regarding the efficacy of these interventions, future RCTs should address the limitations observed in existing research in the literature.

Conclusion

In conclusion, this systematic review and meta-analysis may have found a positive effect of DSME on the clinical and cardiometabolic risk factors, diabetes self-management behaviours and psychosocial well-being of people with T2DM in LMICs. Therefore, DSME interventions may enhance disease management and support to improve self-care strategies for people with T2DM. Further, interventions utilising a face-to-face delivery coupled with periodic ongoing support may be useful in improving glycaemic and lipid control as well as anthropometric measures. This study suggests that ongoing support alongside individualised face-to-face intervention delivery needs to be prioritised in order to improve overall T2DM management in LMICs, with a special emphasis on countries in the lowest income groups.

Supporting information

S1 Table. PRISMA checklist 2020.
(DOCX)

S2 Table. Eligibility criteria (PICOS).
(DOCX)

S3 Table. Search strategy.
(DOCX)

S4 Table. Primary and secondary outcomes.
(DOCX)

S5 Table. Other characteristics (intervention description) of the included studies.
(DOCX)

S6 Table. Risk of bias summary for quasi-experimental studies.
(DOCX)

S7 Table. GRADEpro level of quality evidence assessment.
(DOCX)

S1 Fig. Subgroup meta-analysis results showing the effect of interventions on (A) HbA1c, (B) BMI, (C) LDL, (D) HDL, (E) TG, and (F) TC based on the income level of the country.
(TIF)

S2 Fig. Subgroup meta-analysis results showing the effect of interventions on (A) HbA1c, (B) BMI, (C) LDL, (D) HDL, (E) TG, and (F) TC based on intervention type.
(TIF)

S3 Fig. Subgroup meta-analysis results showing the effect of interventions on (A) HbA1c, (B) BMI, (C) LDL, (D) HDL, (E) TG, and (F) TC based on the mode of delivery of intervention.
(TIF)

S4 Fig. Subgroup meta-analysis results showing the effect of interventions on (A) HbA1c, (B) BMI, (C) LDL, (D) HDL, (E) TG, and (F) TC based on the quality of study.
(TIF)

S5 Fig. Risk of bias summary (red, yellow, and green solid circle represents high risk of bias, some concerns risk of bias, and low risk of bias respectively): Review authors

judgements about risk of bias item for each included study.
(TIF)

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Author Contributions

References

1. Baviskar MP, Rangari S, Mishra S, Mohanta BS. Assessment of a group-based comprehensive diabetes management program to improve glycemic control, quality of life and self-care behavior in patients with type 2 diabetes mellitus in a primary healthcare setting of a metropolitan city in India: CDMP MUM Trial. International Journal of Diabetes in Developing Countries. 2021; 41:156–63.

2. IDF. Diabetes Atlas. International Diabetes Federation. 10th Edition. 2021;ISBN: 978-2-930229-98-0. https://diabetesatlas.org/idfawp/resource-files/2021/07/IDF_Atlas_10th_Edition_2021.pdf

3. WHO. Diabetes, The World Health Organization. https://www.who.int/news-room/fact-sheets/detail/diabetes. 2022.

4. Cade WT. Diabetes-related microvascular and macrovascular diseases in the physical therapy setting. Physical therapy. 2008; 88:1322–35. https://doi.org/10.2522/ptj.20080008 PMID: 18801863

5. Seuring T, Archangelidi O, Suhrcke M. The economic costs of type 2 diabetes: a global systematic review. Pharmacoeconomics. 2015; 33:811–31. https://doi.org/10.1007/s40273-015-0268-9 PMID: 25787932

6. Ettaro L, Songer TJ, Zhang P, Engelgau MM. Cost-of-illness studies in diabetes mellitus. Pharmacoeconomics. 2004; 22:149–64. https://doi.org/10.2165/00019053-200422030-00002 PMID: 14871163

7. Atun R, Davies JI, Gale EA, Bärnighausen T, Beran D, Kengne AP, et al. Diabetes in sub-Saharan Africa: from clinical care to health policy. The lancet Diabetes & endocrinology. 2017; 5:622–67. https://doi.org/10.1016/S2213-8587(17)30181-X PMID: 28688818

8. Xu K, Evans DB, Kawabata K, Zeramdini R, Klavus J, Murray CJ. Household catastrophic health expenditure: a multicountry analysis. The lancet. 2003; 362:111–7. https://doi.org/10.1016/S0140-6736(03)13861-5 PMID: 12867110

9. Bloom DE, Chatterji S, Kowal P, Lloyd-Sherlock P, McKee M, Rechel B, et al. Macroeconomic implications of population ageing and selected policy responses. The Lancet. 2015; 385:649–57. https://doi.org/10.1016/S0140-6736(14)61464-1 PMID: 25468167

10. Moucheraud C, Lenz C, Latkovic M, Wirtz VJ. The costs of diabetes treatment in low-and middle-income countries: a systematic review. BMJ global health. 2019; 4:e001258. https://doi.org/10.1136/bmjgh-2018-001258 PMID: 30899566

11. Spellman CW. Achieving glycemic control: cornerstone in the treatment of patients with multiple metabolic risk factors. Journal of Osteopathic Medicine. 2009; 109:8–13. PMID: 19451256

12. Siddiquea BN, Afroz A, Chowdhury MRK, Savira F, Alif SM, Bhattacharya O, et al. Knowledge, attitudes and practices of COVID-19 in rural Bangladesh: a cross-sectional study. BMJ open. 2023; 13: e064754. https://doi.org/10.1136/bmjopen-2022-064754 PMID: 36792336

13. Rosiek A, Kornatowski T, Frąckowiak-Maciejewska N, Rosiek-Kryszewska A, Wyżgowski P, Leksowski K. Health behaviors of patients diagnosed with type 2 diabetes mellitus and their influence on the patients' satisfaction with life. Therapeutics and clinical risk management. 2016:1783–92. https://doi.org/10.2147/TCRM.S118014 PMID: 27932885

14. Lamptey R, Amoakoh-Coleman M, Djobalar B, Grobbee DE, Adjei GO, Klipstein-Grobusch K. Diabetes self-management education interventions and self-management in low-resource settings; a mixed methods study. Plos one. 2023; 18:e0286974. https://doi.org/10.1371/journal.pone.0286974 PMID: 37450431

15. Fan L, Sidani S. Effectiveness of diabetes self-management education intervention elements: a meta-analysis. Canadian journal of diabetes. 2009; 33:18–26.

16. Kumah E, Otchere G, Ankomah SE, Fusheini A, Kokuro C, Aduo-Adjei K, et al. Diabetes self-management education interventions in the WHO African Region: A scoping review. PloS one. 2021; 16: e0256123. https://doi.org/10.1371/journal.pone.0256123 PMID: 34403455

17. Almutairi N, Hosseinzadeh H, Gopaldasani V. The effectiveness of patient activation intervention on type 2 diabetes mellitus glycemic control and self-management behaviors: a systematic review of RCTs. Primary care diabetes. 2020; 14:12–20. https://doi.org/10.1016/j.pcd.2019.08.009 PMID: 31543458

18. Shrivastava SR, Shrivastava PS, Ramasamy J. Role of self-care in management of diabetes mellitus. Journal of diabetes & Metabolic disorders. 2013; 12:1–5. https://doi.org/10.1186/2251-6581-12-14 PMID: 23497559

19. Funnell MM, Anderson RM. Empowerment and self-management of diabetes. Clinical diabetes. 2004; 22:123–8.

20. Aquino JA, Baldoni NR, Flôr CR, Sanches C, Oliveira CDL, Alves GCS, et al. Effectiveness of individual strategies for the empowerment of patients with diabetes mellitus: a systematic review with meta-analysis. Primary care diabetes. 2018; 12:97–110. https://doi.org/10.1016/j.pcd.2017.10.004 PMID: 29162491

21. Hildebrand JA, Billimek J, Lee J-A, Sorkin DH, Olshansky EF, Clancy SL, et al. Effect of diabetes self-management education on glycemic control in Latino adults with type 2 diabetes: a systematic review and meta-analysis. Patient education and counseling. 2020; 103:266–75. https://doi.org/10.1016/j.pec.2019.09.009 PMID: 31542186

22. Hemmingsen B, Lund SS, Gluud C, Vaag A, Almdal T, Hemmingsen C, et al. Intensive glycaemic control for patients with type 2 diabetes: systematic review with meta-analysis and trial sequential analysis of randomised clinical trials. Bmj. 2011; 343. https://doi.org/10.1136/bmj.d6898 PMID: 22115901

23. He X, Li J, Wang B, Yao Q, Li L, Song R, et al. Diabetes self-management education reduces risk of all-cause mortality in type 2 diabetes patients: a systematic review and meta-analysis. Endocrine. 2017; 55:712–31. https://doi.org/10.1007/s12020-016-1168-2 PMID: 27837440

24. Welch G, Garb J, Zagarins S, Lendel I, Gabbay RA. Nurse diabetes case management interventions and blood glucose control: results of a meta-analysis. Diabetes research and clinical practice. 2010; 88:1–6. https://doi.org/10.1016/j.diabres.2009.12.026 PMID: 20116879

25. Norris SL, Lau J, Smith SJ, Schmid CH, Engelgau MM. Self-management education for adults with type 2 diabetes: a meta-analysis of the effect on glycemic control. Diabetes care. 2002; 25:1159–71. https://doi.org/10.2337/diacare.25.7.1159 PMID: 12087014

26. Pillay J, Armstrong MJ, Butalia S, Donovan LE, Sigal RJ, Vandermeer B, et al. Behavioral programs for type 2 diabetes mellitus: a systematic review and network meta-analysis. Annals of internal medicine. 2015; 163:848–60. https://doi.org/10.7326/M15-1400 PMID: 26414227

27. Sherifali D, Bai JW, Kenny M, Warren R, Ali M. Diabetes self-management programmes in older adults: a systematic review and meta-analysis. Diabetic Medicine. 2015; 32:1404–14. https://doi.org/10.1111/dme.12780 PMID: 25865179

28. Chrvala CA, Sherr D, Lipman RD. Diabetes self-management education for adults with type 2 diabetes mellitus: a systematic review of the effect on glycemic control. Patient education and counseling. 2016; 99:926–43. https://doi.org/10.1016/j.pec.2015.11.003 PMID: 26658704

29. Afable A, Karingula NS. Evidence based review of type 2 diabetes prevention and management in low and middle income countries. World journal of diabetes. 2016; 7:209. https://doi.org/10.4239/wjd.v7.i10.209 PMID: 27226816

30. Lamptey R, Robben MP, Amoakoh-Coleman M, Boateng D, Grobbee DE, Davies MJ, et al. Structured diabetes self-management education and glycaemic control in low-and middle-income countries: a systematic review. Diabetic Medicine. 2022; 39:e14812. https://doi.org/10.1111/dme.14812 PMID: 35179792

31. Lagisetty PA, Priyadarshini S, Terrell S, Hamati M, Landgraf J, Chopra V, et al. Culturally targeted strategies for diabetes prevention in minority population: a systematic review and framework. The Diabetes Educator. 2017; 43:54–77.

32. Guilbert E, Perry R, Whitmarsh A, Sauchelli S. Short-term effectiveness of nutrition therapy to treat type 2 diabetes in low-income and middle-income countries: systematic review and meta-analysis of randomised controlled trials. BMJ open. 2022; 12:e056108. https://doi.org/10.1136/bmjopen-2021-056108 PMID: 35273056

33. O'Donoghue G, O'Sullivan C, Corridan I, Daly J, Finn R, Melvin K, et al. Lifestyle interventions to improve glycemic control in adults with type 2 diabetes living in low-and-middle income countries: A systematic review and meta-analysis of randomized controlled trials (RCTs). International journal of environmental research and public health. 2021; 18:6273. https://doi.org/10.3390/ijerph18126273 PMID: 34200592

34. Mohamed A, Staite E, Ismail K, Winkley K. A systematic review of diabetes self-management education interventions for people with type 2 diabetes mellitus in the Asian Western Pacific (AWP) region. Nursing Open. 2019; 6:1424–37. https://doi.org/10.1002/nop2.340 PMID: 31660170

35. Lamptey R, Amoakoh-Coleman M, Barker MM, Iddi S, Hadjiconstantinou M, Davies M, et al. Change in glycaemic control with structured diabetes self-management education in low-resource settings: randomized trial. Structured diabetes self-management education and glycaemic control in low-resource urban primary care settings. 2023.

36. Lim LL, Lau ES, Kong AP, Davies MJ, Levitt NS, Eliasson B, et al. Aspects of multicomponent integrated care promote sustained improvement in surrogate clinical outcomes: a systematic review and meta-analysis. Diabetes Care. 2018; 41:1312–20. https://doi.org/10.2337/dc17-2010 PMID: 29784698

37. Diriba DC, Leung DY, Suen LK. The effects of diabetes self-management interventions on physiological outcomes in people living with diabetes in Africa: a systematic review and meta-analysis. Diabetic Medicine. 2021; 38:e14501. https://doi.org/10.1111/dme.14501 PMID: 33341999

38. Lamptey R, Amoakoh-Coleman M, Barker MM, Iddi S, Hadjiconstantinou M, Davies M, et al. Change in glycaemic control with structured diabetes self-management education in urban low-resource settings: multicentre randomised trial of effectiveness. BMC Health Services Research. 2023; 23:1–9.

39. Shirinzadeh M, Afshin-Pour B, Angeles R, Gaber J, Agarwal G. The effect of community-based programs on diabetes prevention in low-and middle-income countries: a systematic review and meta-analysis. Globalization and health. 2019; 15:1–13.

40. Page MJ, McKenzie JE, Bossuyt PM, Boutron I, Hoffmann TC, Mulrow CD, et al. The PRISMA 2020 statement: an updated guideline for reporting systematic reviews. International journal of surgery. 2021; 88:105906. https://doi.org/10.1016/j.ijsu.2021.105906 PMID: 33789826

41. The World Bank. World bank country classification by income level. World bank country classification by income level, https://data.worldbank.org/country. 2021.

42. Higgins JP, Savović J, Page MJ, Elbers RG, Sterne JA. Assessing risk of bias in a randomized trial. Cochrane handbook for systematic reviews of interventions. 2019:205–28.

43. Armijo-Olivo S, Stiles CR, Hagen NA, Biondo PD, Cummings GG. Assessment of study quality for systematic reviews: a comparison of the Cochrane Collaboration Risk of Bias Tool and the Effective Public Health Practice Project Quality Assessment Tool: methodological research. Journal of evaluation in clinical practice. 2012; 18:12–8. https://doi.org/10.1111/j.1365-2753.2010.01516.x PMID: 20698919

44. Institute JB. The Joanna Briggs Institute critical appraisal tools for use in JBI systematic reviews: checklist for quasi-experimental studies (non-randomized experimental studies), 2017. JBI_Quasi-Experimental_Appraisal_Tool2017 pdf. 2017.

45. Guyatt GH, Oxman AD, Kunz R, Vist GE, Falck-Ytter Y, Schünemann HJ. What is "quality of evidence" and why is it important to clinicians? Bmj. 2008; 336:995–8. https://doi.org/10.1136/bmj.39490.551019.BE PMID: 18456631

46. GRADEpro G. GRADEpro guideline development tool [software]. McMaster University. 2015; 435.

47. Deeks JJ, Higgins JP, Altman DG, Group CSM. Analysing data and undertaking meta-analyses. Cochrane handbook for systematic reviews of interventions. 2019:241–84.

48. Egger M, Smith GD, Schneider M, Minder C. Bias in meta-analysis detected by a simple, graphical test. Bmj. 1997; 315:629–34. https://doi.org/10.1136/bmj.315.7109.629 PMID: 9310563

49. Higgins JP, Thomas J, Chandler J, Cumpston M, Li T, Page MJ, et al. Cochrane handbook for systematic reviews of interventions version 6.2. The Cochrane Collaboration. 2021.

50. Yagiz G, Akaras E, Kubis H-P, Owen JA. The effects of resistance training on architecture and volume of the upper extremity muscles: A systematic review of randomised controlled trials and meta-analyses. Applied Sciences. 2022; 12:1593.

51. Chow EP, Hassali MA, Saleem F, Aljadhey H. Effects of pharmacist-led patient education on diabetes-related knowledge and medication adherence: A home-based study. Health Education Journal. 2016; 75:421–33.

52. Goldhaber-Fiebert JD, Goldhaber-Fiebert SN, Tristán ML, Nathan DM. Randomized controlled community-based nutrition and exercise intervention improves glycemia and cardiovascular risk factors in type 2 diabetic patients in rural Costa Rica. Diabetes care. 2003; 26:24–9. https://doi.org/10.2337/diacare.26.1.24 PMID: 12502654

53. Grillo MdFF, Neumann CR, Scain SF, Rozeno RF, Beloli L, Perinetto T, et al. Diabetes education in primary care: a randomized clinical trial. Cadernos de Saude Publica. 2016; 32:e00097115. https://doi.org/10.1590/0102-311X00097115 PMID: 27253458

54. Azami G, Soh KL, Sazlina SG, Salmiah M, Aazami S, Mozafari M, et al. Effect of a nurse-led diabetes self-management education program on glycosylated hemoglobin among adults with type 2 diabetes. Journal of diabetes research. 2018; 2018. https://doi.org/10.1155/2018/4930157 PMID: 30225268

55. Huo X, Krumholz HM, Bai X, Spatz ES, Ding Q, Horak P, et al. Effects of mobile text messaging on glycemic control in patients with coronary heart disease and diabetes mellitus: a randomized clinical trial. Circulation: Cardiovascular Quality and Outcomes. 2019; 12:e005805. https://doi.org/10.1161/CIRCOUTCOMES.119.005805 PMID: 31474119

56. Jiang XJ, Jiang H, Lu YH, Liu SL, Wang JP, Tang RS, et al. The effectiveness of a self-efficacy-focused structured education programme on adults with type 2 diabetes: A multicentre randomised controlled trial. Journal of Clinical Nursing. 2019; 28:3299–309. https://doi.org/10.1111/jocn.14908 PMID: 31066115

57. Ju C, Shi R, Yao L, Ye X, Jia M, Han J, et al. Effect of peer support on diabetes distress: a cluster randomized controlled trial. Diabetic Medicine. 2018; 35:770–5. https://doi.org/10.1111/dme.13625 PMID: 29574995

58. Kong J-X, Zhu L, Wang H-M, Li Y, Guo A-Y, Gao C, et al. Effectiveness of the chronic care model in type 2 diabetes management in a community health service center in China: a group randomized experimental study. Journal of diabetes research. 2019; 2019.

59. Li Y, Xu M, Fan R, Ma X, Gu J, Cai X, et al. The effects of intensive nutrition education on late middle-aged adults with type 2 diabetes. International Journal of Environmental Research and Public Health. 2016; 13:897. https://doi.org/10.3390/ijerph13090897 PMID: 27618080

60. Lou Q, Ye Q, Wu H, Wang Z, Ware RS, Xiong Y, et al. Effectiveness of a clinic-based randomized controlled intervention for type 2 diabetes management: an innovative model of intensified diabetes management in Mainland China (C-IDM study). BMJ Open Diabetes Research and Care. 2020; 8: e001030. https://doi.org/10.1136/bmjdrc-2019-001030 PMID: 32107265

61. Muchiri JW, Gericke GJ, Rheeder P. Effect of a nutrition education programme on clinical status and dietary behaviours of adults with type 2 diabetes in a resource-limited setting in South Africa: a randomised controlled trial. Public health nutrition. 2016; 19:142–55. https://doi.org/10.1017/S1368980015000956 PMID: 25872641

62. Mash RJ, Rhode H, Zwarenstein M, Rollnick S, Lombard C, Steyn K, et al. Effectiveness of a group diabetes education programme in under-served communities in South Africa: a pragmatic cluster randomized controlled trial. Diabetic Medicine. 2014; 31:987–93. https://doi.org/10.1111/dme.12475 PMID: 24766179

63. Ramadas A, Chan CKY, Oldenburg B, Hussein Z, Quek KF. Randomised-controlled trial of a web-based dietary intervention for patients with type 2 diabetes: changes in health cognitions and glycemic control. BMC Public Health. 2018; 18:1–13. https://doi.org/10.1186/s12889-018-5640-1 PMID: 29884161

64. Ramli AS, Selvarajah S, Daud MH, Haniff J, Abdul-Razak S, Tg-Abu-Bakar-Sidik TMI, et al. Effectiveness of the EMPOWER-PAR intervention in improving clinical outcomes of type 2 diabetes mellitus in primary care: a pragmatic cluster randomised controlled trial. BMC family practice. 2016; 17:1–18.

65. Tan M, Magarey J, Chee S, Lee L, Tan M. A brief structured education programme enhances self-care practices and improves glycaemic control in Malaysians with poorly controlled diabetes. Health education research. 2011; 26:896–907. https://doi.org/10.1093/her/cyr047 PMID: 21715653

66. Wattana C, Srisuphan W, Pothiban L, Upchurch SL. Effects of a diabetes self-management program on glycemic control, coronary heart disease risk, and quality of life among Thai patients with type 2

diabetes. Nursing & health sciences. 2007; 9:135–41. https://doi.org/10.1111/j.1442-2018.2007.00315.x PMID: 17470188

67. Whittemore R, Vilar-Compte M, De La Cerda S, Delvy R, Jeon S, Burrola-Méndez S, et al. ¡ Sí, Yo Puedo Vivir Sano Con Diabetes! A self-management randomized controlled pilot trial for low-income adults with type 2 diabetes in Mexico City. Current Developments in Nutrition. 2020; 4:nzaa074.

68. Wichit N, Mnatzaganian G, Courtney M, Schulz P, Johnson M. Randomized controlled trial of a family-oriented self-management program to improve self-efficacy, glycemic control and quality of life among Thai individuals with Type 2 diabetes. Diabetes research and clinical practice. 2017; 123:37–48. https://doi.org/10.1016/j.diabres.2016.11.013 PMID: 27918976

69. Zhang Y, Chu L. Effectiveness of systematic health education model for type 2 diabetes patients. International journal of endocrinology. 2018; 2018. https://doi.org/10.1155/2018/6530607 PMID: 30147724

70. Zheng F, Liu S, Liu Y, Deng L. Effects of an outpatient diabetes self-management education on patients with type 2 diabetes in China: a randomized controlled trial. Journal of diabetes research. 2019; 2019.

71. Zhong X, Wang Z, Fisher EB, Tanasugarn C. Peer support for diabetes management in primary care and community settings in Anhui Province, China. The Annals of Family Medicine. 2015; 13:S50–S8. https://doi.org/10.1370/afm.1799 PMID: 26304972

72. Askari A, Jeihooni AK, Kashfi SM, Marzban A, Khiyali Z. The effect of educational program based on belief, attitude, subjective norm, and enabling factors model on changing the metabolic indices in elderly patients with type II diabetes. International journal of preventive medicine. 2018; 9. https://doi.org/10.4103/ijpvm.IJPVM_308_16 PMID: 30210739

73. Didarloo A, Shojaeizadeh D, Alizadeh M. Impact of educational intervention based on interactive approaches on beliefs, behavior, hemoglobin A1c, and quality of life in diabetic women. International journal of preventive medicine. 2016; 7. https://doi.org/10.4103/2008-7802.176004 PMID: 27014430

74. Ebrahimi H, Sadeghi M, Amanpour F, Vahedi H. Evaluation of empowerment model on indicators of metabolic control in patients with type 2 diabetes, a randomized clinical trial study. Primary care diabetes. 2016; 10:129–35. https://doi.org/10.1016/j.pcd.2015.09.003 PMID: 26795772

75. Essien O, Otu A, Umoh V, Enang O, Hicks JP, Walley J. Intensive patient education improves glycaemic control in diabetes compared to conventional education: a randomised controlled trial in a Nigerian tertiary care hospital. PloS one. 2017; 12:e0168835. https://doi.org/10.1371/journal.pone.0168835 PMID: 28045979

76. Gathu CW, Shabani J, Kunyiha N, Ratansi R. Effect of diabetes self-management education on glycaemic control among type 2 diabetic patients at a family medicine clinic in Kenya: A randomised controlled trial. African Journal of Primary Health Care & Family Medicine. 2018; 10:1–9.

77. Goodarzi M, Ebrahimzadeh I, Rabi A, Saedipoor B, Jafarabadi MA. Impact of distance education via mobile phone text messaging on knowledge, attitude, practice and self efficacy of patients with type 2 diabetes mellitus in Iran. Journal of Diabetes & Metabolic Disorders. 2012; 11:1–8. https://doi.org/10.1186/2251-6581-11-10 PMID: 23497632

78. Hosseini S, Shojaeizadeh D, Sanagu A, Vakili M, Mirkarimi K, Jahanshahi R. Effect of educational intervention on self-care behaviors among patients with diabetes: An application of PRECEDE model. Annals of Tropical Medicine and Public Health. 2017; 10.

79. Jain V, Joshi R, Idiculla J, Xavier D. Community health worker interventions in type 2 diabetes mellitus patients: Assessing the feasibility and effectiveness in Rural Central India. Journal of Cardiovascular Disease Research. 2018; 9.

80. Jayasuriya R, Pinidiyapathirage MJ, Jayawardena R, Kasturiratne A, de Zoysa P, Godamunne P, et al. Translational research for diabetes self-management in Sri Lanka: a randomized controlled trial. Primary Care Diabetes. 2015; 9:338–45. https://doi.org/10.1016/j.pcd.2015.01.014 PMID: 25733343

81. Mohammadi S, Karim NA, Talib RA, Amani R. The impact of self-efficacy education based on the health belief model in Iranian patients with type 2 diabetes: a randomised controlled intervention study. Asia Pacific journal of clinical nutrition. 2018; 27:546–55. https://doi.org/10.6133/apjcn.072017.07 PMID: 29737801

82. Myers EF, Trostler N, Varsha V, Voet H. Insights from the diabetes in india nutrition guidelines study: adopting innovations using a knowledge transfer model. Topics in Clinical Nutrition. 2017; 32:69. https://doi.org/10.1097/TIN.0000000000000089 PMID: 28232773

83. Ojieabu WA, Bello SI, Arute JE. Evaluation of pharmacists' educational and counselling impact on patients' clinical outcomes in a diabetic setting. Journal of Diabetology. 2017; 8:7.

84. Samtia AM, Rasool MF, Ranjha NM, Usman F, Javed I. A multifactorial intervention to enhance adherence to medications and disease-related knowledge in type 2 diabetic patients in Southern Punjab, Pakistan. Tropical Journal of Pharmaceutical Research. 2013; 12:851–6.

85. Sanaeinasab H, Saffari M, Yazdanparast D, Zarchi AK, Al-Zaben F, Koenig HG, et al. Effects of a health education program to promote healthy lifestyle and glycemic control in patients with type 2 diabetes: A randomized controlled trial. Primary Care Diabetes. 2021; 15:275–82. https://doi.org/10.1016/j.pcd.2020.09.007 PMID: 33055009

86. Salahshouri A, Zamani Alavijeh F, Mahaki B, Mostafavi F. Effectiveness of educational intervention based on psychological factors on achieving health outcomes in patients with type 2 diabetes. Diabetology & metabolic syndrome. 2018; 10:1–12. https://doi.org/10.1186/s13098-018-0368-8 PMID: 30186372

87. Thanh HTK, Tien TM. Effect of Group Patient Education on Glycemic Control Among People Living with Type 2 Diabetes in Vietnam: A Randomized Controlled Single-Center Trial. Diabetes Therapy. 2021; 12:1503–21.

88. Al-Halaweh AA, Almdal T, O'Rourke N, Davidovitch N. Mobile care teams improve metabolic control for adults with Type II diabetes in the Southern West Bank, Palestine. Diabetes & Metabolic Syndrome: Clinical Research & Reviews. 2019; 13:782–5. https://doi.org/10.1016/j.dsx.2018.11.066 PMID: 30641807

89. Pamungkas RA, Chamroonsawasdi K. Self-management based coaching program to improve diabetes mellitus self-management practice and metabolic markers among uncontrolled type 2 diabetes mellitus in Indonesia: A quasi-experimental study. Diabetes & Metabolic Syndrome: Clinical Research & Reviews. 2020; 14:53–61. https://doi.org/10.1016/j.dsx.2019.12.002 PMID: 31887715

90. Kumari G, Singh V, Jhingan AK, Chhajer B, Dahiya S. Effectiveness of lifestyle modification counseling on glycemic control in type 2 diabetes mellitus patients. Current Research in Nutrition and Food Science. 2018; 6:70.

91. Debussche X, Besançon S, Balcou-Debussche M, Ferdynus C, Delisle H, Huiart L, et al. Structured peer-led diabetes self-management and support in a low-income country: The ST2EP randomised controlled trial in Mali. PLoS One. 2018; 13:e0191262. https://doi.org/10.1371/journal.pone.0191262 PMID: 29357380

92. Yan H, Prista A, Ranadive SM, Damasceno A, Caupers P, Kanaley JA, et al. Effect of aerobic training on glucose control and blood pressure in T2DDM East African males. International Scholarly Research Notices. 2014; 2014. https://doi.org/10.1155/2014/864897 PMID: 24729886

93. Azami G, Soh KL, Sazlina S-G, Salmiah MS, Aazami S. Behavioral interventions to improve self-management in Iranian adults with type 2 diabetes: a systematic review and meta-analysis. Journal of Diabetes & Metabolic Disorders. 2018; 17:365–80. https://doi.org/10.1007/s40200-018-0376-0 PMID: 30918872

94. Shiferaw WS, Akalu TY, Desta M, Kassie AM, Petrucka PM, Aynalem YA. Effect of educational interventions on knowledge of the disease and glycaemic control in patients with type 2 diabetes mellitus: a systematic review and meta-analysis of randomised controlled trials. BMJ open. 2021; 11:e049806. https://doi.org/10.1136/bmjopen-2021-049806 PMID: 34887271

95. Group UPDS. Effect of intensive blood-glucose control with metformin on complications in overweight patients with type 2 diabetes (UKPDS 34). The Lancet. 1998; 352:854–65.

96. Group AC. Intensive blood glucose control and vascular outcomes in patients with type 2 diabetes. New England journal of medicine. 2008; 358:2560–72. https://doi.org/10.1056/NEJMoa0802987 PMID: 18539916

97. Group UPDS. Intensive blood-glucose control with sulphonylureas or insulin compared with conventional treatment and risk of complications in patients with type 2 diabetes (UKPDS 33). The lancet. 1998; 352:837–53.

98. Odgers-Jewell K, Ball L, Kelly J, Isenring E, Reidlinger D, Thomas R. Effectiveness of group-based self-management education for individuals with Type 2 diabetes: a systematic review with meta-analyses and meta-regression. Diabetic Medicine. 2017; 34:1027–39. https://doi.org/10.1111/dme.13340 PMID: 28226200

99. Shirvani T, Javadivala Z, Azimi S, Shaghaghi A, Fathifar Z, Devender Bhalla H, et al. Community-based educational interventions for prevention of type II diabetes: a global systematic review and meta-analysis. Systematic reviews. 2021; 10:1–12.

100. Chen C-N, Chuang L-M, Korivi M, Wu Y-T. Home-based exercise may not decrease the insulin resistance in individuals with metabolic syndrome. Journal of Physical Activity and Health. 2015; 12:74–9. https://doi.org/10.1123/jpah.2013-0284 PMID: 24509907

101. Bilgin A, Muz G, Yuce GE. The Effect of Motivational Interviewing on Metabolic Control and Psychosocial Variables in Individuals Diagnosed with Diabetes: Systematic Review and Meta-Analysis. Patient Education and Counseling. 2022. https://doi.org/10.1016/j.pec.2022.04.008 PMID: 35501227

102. Wangberg SC. An Internet-based diabetes self-care intervention tailored to self-efficacy. Health education research. 2008; 23:170–9. https://doi.org/10.1093/her/cym014 PMID: 17412717

103. Peyrot M, Rubin RR. Modeling the effect of diabetes education on glycemic control. The Diabetes Educator. 1994; 20:143–8. https://doi.org/10.1177/014572179402000210 PMID: 7851228

104. Bandura A, Watts RE. Self-efficacy in changing societies. Springer; 1996.

105. Walker RJ, Smalls BL, Hernandez-Tejada MA, Campbell JA, Egede LE. Effect of diabetes self-efficacy on glycemic control, medication adherence, self-care behaviors, and quality of life in a predominantly low-income, minority population. Ethnicity & disease. 2014; 24:349.

106. Creamer J, Attridge M, Ramsden M, Cannings-John R, Hawthorne K. Culturally appropriate health education for Type 2 diabetes in ethnic minority groups: an updated Cochrane Review of randomized controlled trials. Diabetic Medicine. 2016; 33:169–83. https://doi.org/10.1111/dme.12865 PMID: 26202820

107. Cheng L, Sit JW, Choi Kc, Chair Sy, Li X, He Xl. Effectiveness of interactive self-management interventions in individuals with poorly controlled type 2 diabetes: A meta-analysis of randomized controlled trials. Worldviews on Evidence-Based Nursing. 2017; 14:65–73. https://doi.org/10.1111/wvn.12191 PMID: 27984672

108. Rubin RR, Peyrot M. Quality of life and diabetes. Diabetes/metabolism research and reviews. 1999; 15:205–18. https://doi.org/10.1002/(sici)1520-7560(199905/06)15:3<205::aid-dmrr29>3.0.co;2-o PMID: 10441043

109. Keers JC, Bouma J, Links TP, ter Maaten JC, Gans RO, Wolffenbuttel BH, et al. One-year follow-up effects of diabetes rehabilitation for patients with prolonged self-management difficulties. Patient education and counseling. 2006; 60:16–23. https://doi.org/10.1016/j.pec.2004.10.013 PMID: 16332466

110. Forlani G, Zannoni C, Tarrini G, Melchionda N, Marchesini G. An empowerment-based educational program improves psychological well-being and health-related quality of life in Type 1 diabetes. Journal of endocrinological investigation. 2006; 29:405–12. https://doi.org/10.1007/BF03344123 PMID: 16794363

111. Wolf AM, Conaway MR, Crowther JQ, Hazen KY, L. Nadler J, Oneida B, et al. Translating lifestyle intervention to practice in obese patients with type 2 diabetes: Improving Control with Activity and Nutrition (ICAN) study. Diabetes care. 2004; 27:1570–6. https://doi.org/10.2337/diacare.27.7.1570 PMID: 15220230

112. Zhang X, Norris SL, Chowdhury FM, Gregg EW, Zhang P. The effects of interventions on health-related quality of life among persons with diabetes: a systematic review. Medical care. 2007:820–34. https://doi.org/10.1097/MLR.0b013e3180618b55 PMID: 17712252

113. Siefken K, Varela AR, Waqanivalu T, Schulenkorf N. Physical activity in low-and middle-income countries: Routledge; 2021.

114. Robson N, Hosseinzadeh H. Impact of telehealth care among adults living with type 2 diabetes in primary care: a systematic review and meta-analysis of randomised controlled trials. International journal of environmental research and public health. 2021; 18:12171. https://doi.org/10.3390/ijerph182212171 PMID: 34831925

115. Association ADE. The International Centre for Allied Health Evidence (2014). Rapid review of literature for consumer centred care in people with diabetes. Technical Report. Prepared for the Australian Diabetes Educators Association. 2014.

116. Brown-Deacon C, Brown T, Creech C, McFarland M, Nair A, Whitlow K. Can follow-up phone calls improve patients self-monitoring of blood glucose? Journal of clinical nursing. 2017; 26:61–7. https://doi.org/10.1111/jocn.13367 PMID: 27862497

117. Schulz KF, Altman DG, Moher D. CONSORT 2010 statement: updated guidelines for reporting parallel group randomised trials. Journal of Pharmacology and pharmacotherapeutics. 2010; 1:100–7. https://doi.org/10.4103/0976-500X.72352 PMID: 21350618