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REVIEW ARTICLE

A comparative review of nutrition education intervention duration and impact on reduction of prediabetes or Type 2 diabetes mellitus among adults aged 45 years or older

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Abstract

Prediabetes and Type 2 diabetes mellitus (T2DM) is increasingly prevalent and both conditions have a variety of comorbidities. There are many programs aimed at the reduction or prevention of prediabetes and/or T2DM. However, only a few studies have evaluated the effect of intervention duration and evidence-based frameworks on specific populations at risk for prediabetes or T2DM. This review evaluated evidence-based lifestyle intervention programs to determine whether the duration of programming relates to the efficacy of evidence-based lifestyle change interventions. The aim was to assess relevant outcomes of these interventions in prediabetic or T2DM individuals aged 45 and older. The PRISMA framework was followed. Searches systematically screened and evaluated 2654 articles. Thirteen articles met the inclusion/exclusion criteria. Databases searched included: PubMed; SCOPUS; ProQuest; Biomed Central; SpringerLink; ScienceDirect; EBSCOHost; JSTOR; Taylor & Francis; Wiley Online; BioOne; CINAHL; SAGE Journal; and Google Scholar (2009–2022). Identifying the most effective timeframe for lifestyle intervention programming to reduce the risks associated with prediabetes/T2DM can help providers develop appropriate educational initiatives for patients at risk for pre-diabetes and/or T2DM. After screening, there were 13 studies which met the review criteria. All of the studies included in this comparative review used evidence-based interventions. Evidence-based lifestyle intervention programs that are ≥12 months produced significant and consistent results in mediating outcomes related to prediabetes/T2DM than <12-month programs in adults aged 45 years and older.

KEYWORDS
adults 45 and older, HbA_{1c}, intervention duration, nutrition education, prediabetes, Type 2 diabetes mellitus

1 | INTRODUCTION

Prediabetes is a serious but potentially reversible health condition defined by abnormal cellular responses leading to increased glucose in the bloodstream (CDC, 2020; Mayo Clinic, 2021). In patients with prediabetes, HbA_{1c} is not high enough (<6.4%) to be classified as Type 2 Diabetes Mellitus (T2DM) (≥6.5%) but is elevated above normal levels (>5.7%) (CDC, 2021b). Remaining in a prediabetic state can increase risk of complications including blindness and amputations, the development of cardiovascular disease, renal disease,

metabolic syndrome, stroke, and progression to T2DM (American Diabetes Association, 2021; CDC, 2020; Mayo Clinic, 2021; Grundy Scott, 2012). Risk factors for prediabetes and T2DM include, but are not limited to, being overweight (BMI 25 to <30) or obese (BMI 30 or higher), being aged 45 years or older, having a family history of T2DM, having a poor diet, and physical inactivity (CDC, 2019a, 2020; Mayo Clinic, 2021; National institute of diabetes and digestive and kidney diseases, 2018). Determinants affecting the development and progression of prediabetes, such as cost of healthy foods and perceived lack of time for health behaviour activities like shopping for and preparing healthy foods/meals or incorporating physical activity into a daily routine, may lead to increased intake of convenience foods over nutritious alternatives in individuals consuming a westernised dietary pattern and/or in impoverished populations (Amer et al., 2020; CDC, 2021a; Escoto et al., 2012; French et al., 2019; Naja et al., 2015). Food choices based on convenience, cost, or availability can lead to diets that are low in nutrients but high in calories, sodium, saturated fats, and added sugars. Dietary and lifestyle patterns that increase such food choices may increase the risk of prediabetes and obesity (Drewnowski & Eichelsdoerfer, 2010; Escoto et al., 2012; French et al., 2019). To reduce the incidence and severity of prediabetes, studies have evaluated the use of lifestyle change programs in adult populations (Amer et al., 2020; Arens et al., 2018; Baker et al., 2011; Davies et al., 2016; Diabetes Prevention Program Research Group, 2002; Dunkley et al., 2014; Fianu et al., 2016; Gillison et al., 2015; Knowler et al., 2002; Mudaliar et al., 2016; Portero McLellan et al., 2014). Some of these programs have shown lifestyle interventions may lower the risk of prediabetes and associated comorbidities by encouraging healthy behaviours such as increased exercise, body weight reduction, and body weight maintenance (up to 7%) (Amer et al., 2020; Baker et al., 2011; Diabetes Prevention Program Research Group, 2002; Dunkley et al., 2014; Fianu et al., 2016; Gillison et al., 2015; Knowler et al., 2002; Mudaliar et al., 2016). However, only a few studies have evaluated the effect of nutrition education intervention duration and evidence-based frameworks on specific populations at-risk for or diagnosed with prediabetes or T2DM (Association of Diabetes Care & Education Specialists, 2020; CDC, 2019b; Diabetes Prevention Program Research Group, 2002).

This comparative analysis, conducted following the PRISMA framework (Moher et al., 2009), reviewed the literature to determine the effect of time in relation to the efficacy of evidence-based lifestyle change interventions and to assess relevant outcomes of these interventions in prediabetic or T2DM individuals aged 45 and older. The aim of the review was to determine if program intervention durations ≥12-month, compared to <12-month programs, were as or more effective at normalising indicators associated with reduction of prediabetes and/or T2DM including: 5–7% weight loss and/or maintaining post-intervention weight loss, an $HbA_{1c} < 5.7$, and/or lowering incidence of prediabetes/T2DM in adults aged 45 years and older who have or are at risk for prediabetes or T2DM. Additionally, current literature on lifestyle change interventions methods and frameworks was evaluated to determine best practices for future design of prediabetes intervention programs.

What is known about this topic and what this paper adds

- Nutrition lifestyle education interventions ≥12 months consistently lead to weight loss, HbA_{1c} reduction, and prediabetes prevention.
- Nutrition lifestyle interventions benefit from development, design, and implementation based on known program planning frameworks.
- Expanded research efforts including stratified age categories and consistent diabetic indicators is recommended.

2 | METHODS

The protocol used to determine article quality for this review was based on the Academy of Nutrition and Dietetics Evidence Analysis library (EAL) and the review process was guided by the PRISMA framework (see Figure 1) (Academy of Nutrition and Dietetics, 2016; Moher et al., 2009). Searches were performed in the following databases—PubMed; SCOPUS; ProQuest; Biomed Central; SpringerLink; ScienceDirect; EBSCOHost; JSTOR; Taylor & Francis; Wiley Online; BioOne; CINAHL; SAGE Journal; and Google Scholar. Key terms and MeSH phrases (see Table 1) were used for the search. Initial screening of articles evaluated the title and abstract of the study and a secondary screening evaluated the studies for relevancy, to remove duplicates, and assess for eligibility. The review was limited to studies published between 2009 and 2022 (see Table 2). Additionally, the inclusion/exclusion criteria limited the search to studies published in English, evidence-based studies, and a minimum age of 45 years or older among other criteria (see Table 2). Studies that did not include an evidence-based lifestyle intervention were excluded (see Table 2).

3 | RESULTS

A total of 13 published studies met the inclusion criteria and were analysed for this comparative review. Five ≥12-month intervention studies and eight <12-month intervention studies were included (see Table 3). Each study was evaluated and given a quality rating based on the Academy of Nutrition and Dietetics EAL quality criteria checklist (Academy of Nutrition and Dietetics, 2016). Bias was assessed for each study and is addressed in the limitations section of this review.

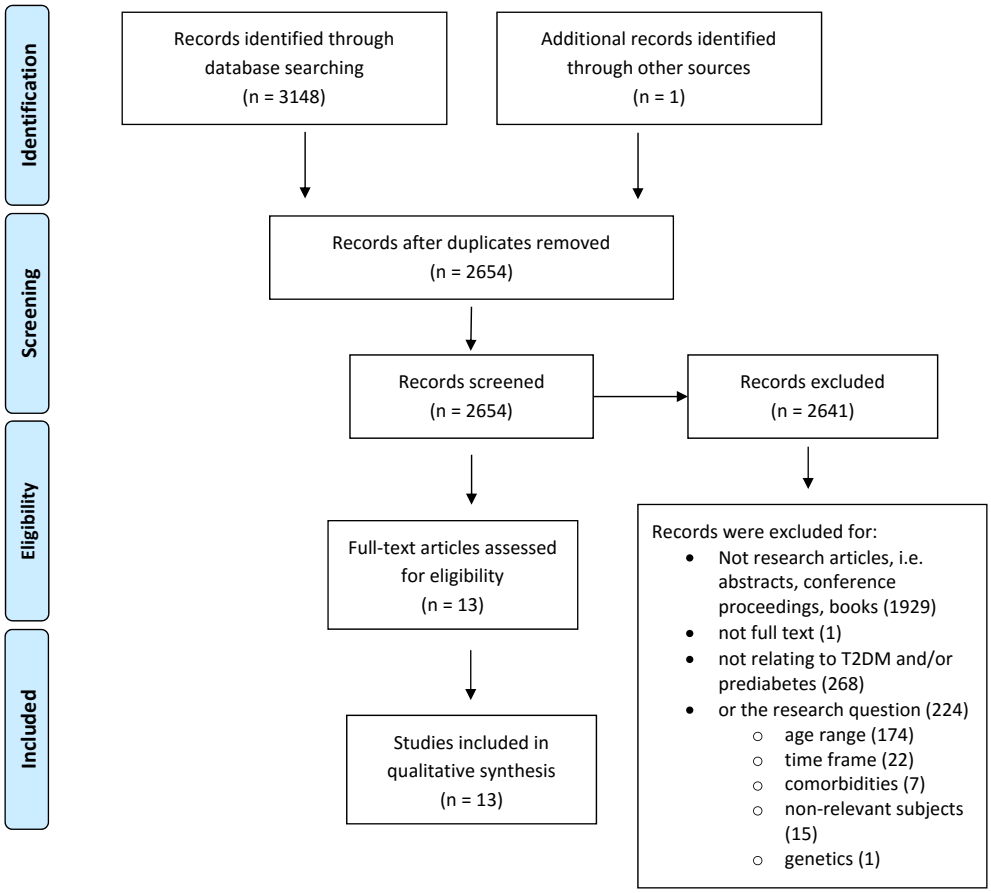

FIGURE 1 PRISMA flow diagram.

TABLE 1 MeSH search terms used

Search terms related to the population	Search terms related to the intervention	Search terms related to the intervention	Search terms related to outcomes or effects
Adults aged 45 years and older who have or are at risk for prediabetes or type 2 diabetes (T2DM)	A ≥ 12-month evidence-based lifestyle intervention program	A < 12-month evidence-based lifestyle intervention program	5–7 percent weight loss and/or maintaining post-intervention weight loss; an $HbA_{1c} < 5.7$; and/or lowering incidence of prediabetes/T2DM
Adult Middle aged (MeSH) 45–65 years old Aged 65–75 years old (MeSH) Prediabetes Prediabetic state (MeSH) Diabetes Mellitus, Type 2 (MeSH)	Primary prevention (MeSH) Early medical intervention (MeSH) Education (MeSH) Time factors (MeSH) Curriculum (MeSH) Health Education (MeSH)	Primary prevention (MeSH) Early medical intervention (MeSH) Education (MeSH) Time factors (MeSH) Curriculum (MeSH) Health Education (MeSH)	Weight loss (MeSH) Weight reduction programs (MeSH) Haemoglobin A, glycated (MeSH) HbA_{1c} (MeSH) Body weight maintenance (MeSH)

3.1 | Intervention duration: ≥12 months

A prospective RCT (n = 434) evaluating the efficacy of a modified Chinese type 2 diabetes prevention lifestyle intervention in rural Chinese adults found significant weight loss ($p < 0.001$), reduction in HbA_{1c} ($p = 0.002$), and reduction in the incidence of T2DM ($p < 0.001$) at year one as well as significant reduction in the incidence of T2DM ($p = 0.041$) at 12 months follow-up in the intervention group compared to the control group (Hu et al., 2017). Similarly, an 8-year RCT ($n = 4585$) found that in American adults, an intensive lifestyle intervention (ILI) adapted from the DPP had significant effects including initial weight loss, initial weight loss ≥5%, and initial weight loss ≥10% at the endpoint of the intervention ($p < 0.001$) in the intervention group compared to the control (Look AHEAD Research Group, 2014). Likewise, a 4-year RCT ($n = 4503$) evaluating the effect of an ILI adapted from the DPP in American adults showed the intervention group experienced statistically significant weight loss ($p < 0.001$) and reduction in the incidence of T2DM ($p < 0.001$) at year 1 with statistically significant, but

TABLE 2 Inclusion/exclusion criteria

Criteria	Inclusion	Exclusion
Age	Adults ≥ 45 years old	Adults < 45 years old
Setting	Outpatient	In patient
Health status	Healthy, with normal risk factors associated with obesity, T2DM, or prediabetes	Patients with other diagnosed comorbidities or poor prognosis. Excludes normal risk factors associated with obesity, T2DM, or prediabetes
Problem/Condition	Healthy adults that have been diagnosed with prediabetes or T2DM	Patient has other serious health issues
Intervention	Included an evidence-based lifestyle intervention	Did not include an evidence-based lifestyle intervention
Intervention model	Based on at least one theory or behavioural change model or on established evidence-based programs such as the Diabetes Prevention Program (DPP)	Does not include theory or behavioural change model
Intervention delivery	Delivered by trained educators	Not delivered by trained educator
Number of educational sessions	Two or more educational sessions	Less than two educational sessions
Behavioural change curricula	Goal setting, lifestyle change evaluations, and biometric change evaluations such as weight loss assessments	Does not include curricula
Size of study groups	The sample size must have at least 10 individuals	A sample size with less than 10 individuals
Study drop out rate	Less than 20%	Greater than 20%
Language	English	Other than English
Duration of intervention	≥12 month or < 12 month	N/A
Measurements used for analysis	Outcomes related to at least one indicator of pre-diabetes	No outcomes related to pre-diabetes
Study design preferences	Primary research, Randomised Controlled Trial, Retrospective, Observational	Systematic Review, Meta-analysis
Year range	2009–2022	<2009
Authorship	Only the newest article by the same author will be accepted unless the study population is different, or unless there is a relevant follow-up period	Studies by the same author will be excluded unless the study population is different, or unless there is a relevant follow-up period
Other	Full text articles only	Articles without full text will be excluded

decreasing, level of weight loss ($p < 0.001$) and reduction in the incidence of T2DM ($p < 0.001$) in year 4 compared with the control group (Gregg et al., 2012). Furthermore, a 4-year RCT ($n = 4815$) evaluating an ILI adapted from the DPP in American adults found a significant effect on initial weight loss ($p < 0.0001$), initial weight loss ≥7% ($p < 0.0001$), and initial weight loss ≥10% ($p < 0.0001$) in the intervention group at year 4 compared to the control (Wadden et al., 2011). Finally, an RCT ($n = 4959$) evaluating an ILI adapted from the DPP found American adults experienced significant weight loss in year 1, initial weight loss ≥7%, and initial weight loss ≥10% ($p < 0.001$) in the intervention group compared to the control (Wadden et al., 2009).

3.2 | Intervention duration: <12 months

An observational study with a pre-post design evaluating a low-cost supervised walking program ($n = 56$) found that in highly motivated Dutch adults who had T2DM ($n = 30$) or were at risk for T2DM ($n = 26$) there was a significant decrease in body weight ($p < 0.01$) and, more specifically in participants with T2DM and a pre-study $HbA_{1c} > 53$ mmol/mol ($n = 8$), there was a significant reduction in HbA_{1c} ($p = 0.03$) over the 28-week program (Hoogendoorn et al., 2019). Similarly, a longitudinal study ($n = 66$) evaluating the efficacy of using diabetes conversation maps with a weight loss program in elderly Italians found significant weight loss in the intervention group ($p < 0.0001$) compared with the control at week 4, and a significant reduction in HbA_{1c} ($p < 0.0001$) for the intervention group compared to the control at the 3-month follow-up (Defeudis et al., 2018; Kewming et al., 2016).

Additionally, an RCT ($n = 60$) found that participants in a culturally adapted DPP intervention for Chinese immigrants (12 bi-weekly core sessions) in New York City demonstrated significant weight loss at 6 months ($p = 0.0001$) and maintained weight loss at a 12-month follow-up ($p = 0.0003$) as well as a significant reduction in HbA_{1c} at a 12-month follow-up ($p < 0.05$) in the intervention group compared to the control (Yeh et al., 2016). Likewise, a retrospective analysis evaluating year 1 results of a 6-month lifestyle intervention called the Diet-Exercise-Activity-Lifestyle program in American adults ($n = 92$) found significant average weight loss in participants at month 6 ($p < 0.001$) and at month 12 ($p = 0.008$) (Bersoux et al., 2010; Swanson et al., 2012).

Providing additional support for programs that are <12 months in duration, a pilot randomised clinical trial ($n = 62$) evaluating the

TABLE 3 Study overview table for included ≥12-month and <12-month evidence-based lifestyle intervention programs

Author, year, Study design, country, funding source	Quality grade (+, −, Ø)	Study purpose	Study population	Intervention and setting	Outcome measures	Results/Conclusion
≥12-month evidence-based lifestyle intervention programs +						
Author, year: Hu et al., 2017. Study Design: Prospective randomised controlled trial Country: China Funding Source: None reported	+	The purpose of this study was to determine if the intervention, a modified Chinese type 2 diabetes prevention lifestyle intervention, could prevent type 2 diabetes (T2DM), and reduce body weight, plasma glucose, and HbA_{1c} over the control, standard health advice, in Chinese adults who live in rural China, aged 60 years and older, with prediabetes (diagnosed by oral glucose tolerance tests: impaired fasting glucose (IFG), impaired glucose tolerance (IGT), or IFG and IGT, 1999 WHO criteria).	This prospective randomised controlled trial focused on Chinese adults who live in rural China, aged 60 years and older, with prediabetes (diagnosed by oral glucose tolerance tests: impaired fasting glucose (IFG), impaired glucose tolerance (IGT), or IFG and IGT, 1999 WHO criteria). The participants were randomly assigned to either the intervention (n = 214) or the control (n = 220).	Intervention (4-part): Modified "Chinese type 2 diabetes prevention guide" 1. Lifestyle education: Program materials: "Chinese type 2 diabetes prevention guide" – used to create program materials Session duration: 60-minutes covering topics including nutrition and exercise—every 3 months provided by intervention study team (IST) 2. Lifestyle intervention: instructions also given every 3 months on subjects including calculating calories 3. Self-monitoring blood glucose (SMBG): training occurred - reported: 1st of every month covering topics - finger sticks Provided by: public health professionals 4. Helping Each Other Group (HEOG): Number of participants /groups: 5–7 given/ assigned at first intervention with weekly reminders and monthly reminders given by group assigned person Control: *Standard health advice including dietary changes provided* every 6 months by the IST	Incidence of T2DM Body weight HbA_{1c}	Body weight reduction ($p < 0.001$) HbA_{1c} reduction ($p = 0.002$) reduction in the incidence of type 2 diabetes (T2DM) ($p < 0.001$) at year 1, and in the incidence of T2DM ($p = 0.041$) at 12 months follow-up, in the intervention versus the control
Author, year: Look AHEAD Research Group., 2014. Study Design: Randomised controlled trial Country: USA Funding Source: Primary funding: The National Institutes of Health, see article for all funding	+	The purpose of this study was to determine if at year 8 the intervention, a long-term intensive lifestyle intervention (ILI) adapted from the DPP, could reduce initial body weight, initial body weight ≥5%, and initial body weight ≥ 10% over the control, diabetes support and education (DSE), in American adults with type 2 diabetes (T2DM), BMI ≥25 kg/m^2, ages 45–76 years old.	This randomised controlled trial, part of the multicentred Look AHEAD (Action for Health in Diabetes) study, evaluated results at year 8. The focus was on American adults with type 2 diabetes (T2DM), BMI ≥25 kg/m^2, ages 45–76 years old. The participants were randomly assigned to either the intervention ($n = 2310$) or the control ($n = 2275$).	Intervention: Intensive lifestyle intervention (ILI) adapted from the DPP Years 2–8: Individual sessions: lifestyle counselling once per month, in person, 20–30 minutes per session with a follow up phone call ~2 weeks later, and monthly group meetings with options to attend a refresher group (6–8 weeks) and/or a national campaign (8–10 weeks) Key focuses: year 1 weight reduction/ maintenance increased/maintained physical activity Control: Diabetes support and education (DSE) program Group sessions: three 1-h group meetings per year, for the first four years, 1 meeting per year after that Key focuses: standard care (diet, exercise)	Body weight	Initial weight loss, initial weight loss ≥5%, and initial weight loss ≥10% at year eight ($p < 0.001$) compared to the control

(Continues)

TABLE 3 (Continued)

Author, year, Study design, country, funding source	Quality grade (+, −, Ø)	Study purpose	Study population	Intervention and setting	Outcome measures	Results/Conclusion
Author, year: Gregg et al., 2012. Study Design: Randomised controlled trial Country: USA Funding Source: Primary funding: The National Institutes of Health, see article for all funding	+	The purpose of this study was to determine if at years 1–4 the intervention, a long-term intensive lifestyle intervention (ILI) adapted from the DPP, could achieve partial or complete remission of type 2 diabetes (T2DM) to pre-diabetic or nondiabetic levels (fasting plasma glucose <126 mg/dl, HbA_{1c} < 6.5%, no diabetes medication) and reduce body weight over the control, the diabetes support and education (DSE), in American adults with T2DM, not on diabetes medication, with a fasting glucose of ≥126 mg/dl, an HbA_{1c} ≥ 6.5%, BMI ≥25 kg/m^2, between 45–76 years old.	This randomised controlled trial, part of the multicentred Look AHEAD (Action for Health in Diabetes) study, evaluated results for years 1–4. The focus was on American adults with type 2 diabetes (T2DM), not on diabetes medication, a fasting glucose of ≥126 mg/dl, an HbA_{1c} ≥ 6.5%, BMI ≥25 kg/m^2, between 45–76 years old. The participants were randomly assigned to either the intervention (n = 2241) or the control (n = 2262).	Intervention: Intensive lifestyle intervention (ILI) adapted from the DPP Year 1: Months 1–6: group sessions (*n* = 10–20) led by lifestyle councillors, 60–75 minutes per session, group sessions occurred during weeks 1–3 of each month with one individual session (20–30 min) during week 4 of that same month Months 7–12: monthly individual sessions continued; group sessions decreased to 2 sessions per month Key focuses: weight reduction and increased physical activity Years 2–8: Individual sessions: lifestyle counselling once per month, in person, 20–30 min per session with a follow up phone call ~2 weeks later, and monthly group meetings with options to attend a refresher group (6–8 weeks) and/or a national campaign (8–10 weeks) Key focuses: year 1 weight reduction/maintenance increased/maintained physical activity Control: Diabetes support and education (DSE) program Group sessions: three 1-h group meetings per year, for the first four years, 1 meeting per year after that Key focuses: standard care (diet, exercise)	Incidence of T2DM Body weight/ maintenance	Reduction in incidence of type 2 diabetes (T2DM) and weight loss were both significant ($p < 0.001$) at year 1, reduction in incidence of T2DM and weight loss in year 4 were both significant ($p < 0.001$) for the intervention compared to the control
Author, year: Wadden et al., 2011. Study Design: Randomised controlled trial Country: USA Funding Source: Primary funding: The National Institutes of Health, see article for all funding	+	The purpose of this study was to determine if at year 4 the intervention, a long-term intensive lifestyle intervention (ILI) adapted from the DPP, could reduce initial weight, initial weight ≥7%, and initial weight ≥ 10% when compared to the control, diabetes support and education (DSE), in American adults with type 2 diabetes (T2DM), BMI ≥25 kg/m^2, ages 45–76 years old.	This randomised controlled trial, part of the multicentred Look AHEAD (Action for Health in Diabetes) study, evaluated results through year 4. The focus was on American adults with type 2 diabetes (T2DM), BMI ≥25 kg/m^2, ages 45–76 years old. The participants were randomised into either the intervention (*n* = 2419) or the control (n = 2396).	Intervention: Intensive lifestyle intervention (ILI) adapted from the DPP Years 2–8: Individual sessions: lifestyle counselling once per month, in person, 20–30 min per session with a follow up phone call ~2 weeks later, and monthly group meetings with options to attend a refresher group (6–8 weeks) and/or a national campaign (8–10 weeks) Key focuses: year 1 weight reduction/ maintenance increased/maintained physical activity Control: Diabetes support and education (DSE) program Group sessions: three 1-h group meetings per year, for the first four years, 1 meeting per year after that Key focuses: standard care (diet, exercise)	Body weight	Initial weight loss ($p < 0.0001$), initial weight loss ≥7% ($p < 0.0001$), and initial weight loss ≥10% ($p < 0.0001$) compared to the control

TABLE 3 (Continued)

Author, year, Study design, country, funding source	Quality grade (+, −, Ø)	Study purpose	Study population	Intervention and setting	Outcome measures	Results/Conclusion
Author, year: Wadden et al., 2009. Study Design: Randomised controlled trial Country: USA Funding Source: Primary funding: The National Institutes of Health, see article for all funding	+	The purpose of this study was to determine if at year 1 the intervention, a long-term intensive lifestyle intervention (ILI) adapted from the DPP, could achieve average initial body weight loss ≥7% compared to the control, diabetes support and education (DSE), in American adults with type 2 diabetes (T2DM), BMI ≥25 kg/m^2, blood pressure ≤ 160/100 mm Hg, HbA_{1c} ≤ 11%, triglyceride levels <600 mg/dl, ages 45–74 years old.	This randomised controlled trial, part of the multicentred Look AHEAD (Action for Health in Diabetes) study, evaluated year 1 results. The focus was on American adults with type 2 diabetes (T2DM), BMI ≥25 kg/m^2, blood pressure ≤ 160/100 mm Hg, HbA_{1c} ≤ 11%, triglyceride levels <600 mg/dl, ages 45–74 years old. The participants were randomised in either the intervention (n = 2496) or the control (n = 2463).	Intervention: Intensive lifestyle intervention (ILI) adapted from the DPP Year 1: Months 1–6: group sessions (n = 10–20) led by lifestyle councillors, 60–75 min per session, group sessions occurred during weeks 1–3 of each month with one individual session (20–30 min) during week 4 of that same month Months 7–12: monthly individual sessions continued; group sessions decreased to 2 sessions per month Key focuses: weight reduction and increased physical activity Control: Diabetes support and education (DSE) program Group sessions: three 1-h group meetings per year, for the first four years, 1 meeting per year after that Key focuses: standard care (diet, exercise)	Body weight	Initial weight loss, initial weight loss ≥7%, and initial weight loss ≥10% (p < 0.001) in the intervention vs the control
+ All 5 ≥ 12-month evidence-based lifestyle intervention programs (100%) resulted in significant reductions in weight, and/or HBA_{1c}, and/or T2DM incidence						
<12-month evidence-based lifestyle intervention programs ±						
Author, year: Hoogendoorn et al., 2019. Study Design: Observational study (pre-post design) Country: Netherlands Funding Source: None reported	+	The purpose of this study was to determine if the intervention, a low-cost supervised walking program, could reduce body weight, HbA_{1c}, and improve health status, in highly motivated Dutch adults that either had or were at risk for type 2 diabetes (T2DM), average age of 60.6 (±10 years).	This observational study (pre-post design) focused on highly motivated Dutch adults, that either had or were at risk for type 2 diabetes (T2DM), average age of 60.6 (±10 years). The 56 participants were divided into groups based on whether they had T2DM (n = 30) or were at risk for T2DM (n = 26).	Intervention: Supervised walking program: Nijkerk challenge (NC) Total duration: 28 weeks Structure: supervised groups of participants walked once per week Supervisors: healthcare professionals including RD's and general practitioners Level of intensity: dependent upon participant (had to be able to walk a minimum of 6 km) Additional support: encouraged to exercise outside of the walking program, educational sessions and cooking classes were offered	Body weight HbA_{1c}	Reduction of body weight (p < 0.01) and in participants (n = 8) with type 2 diabetes and a pre-study HbA_{1c} > 53 mmol/mol had a significant reduction in HbA_{1c} (p = 0.03)

(Continues)

TABLE 3 (Continued)

Author, year, Study design, country, funding source	Quality grade (+, −, Ø)	Study purpose	Study population	Intervention and setting	Outcome measures	Results/Conclusion
Author, year: Mash et al., 2014. Study Design: Pragmatic cluster randomised controlled trial Country: South Africa Funding Source: BRIDGES Grant, Chronic Diseases Initiative for Africa, and Stellenbosch University, see article for all funding	Ø	The purpose of this study was to determine if the intervention, a group education lifestyle intervention, could improve diabetes self-care, achieve 5% weight loss, and reduce HbA_{1c} by 1% over the control, usual education, in South African adults with type 2 diabetes (T2DM), average age 56.1 (±11.6) years old.	This pragmatic cluster randomised controlled trial focused on South African adults with type 2 diabetes (T2DM) average age 56.1 (±11.6) years old. The participants were randomly assigned to either the intervention ($n = 710$) or the control ($n = 860$).	Intervention: Group education lifestyle intervention Session duration: 60-min per session Number of sessions: 4 sessions intended to be held monthly, guided by trained staff using motivational interviewing principles Follow-up: 12 months topics included lifestyle modification including portion control and stress management and understanding medications, diabetes, and complication mitigation Control: Usual education included educational talks and individual counselling	Body weight HbA_{1c}	No statistical significance at 12 months for (weight loss ($p = 0.392$) and HbA_{1c} ($p = 0.967$))
Author, year: Defeudis G, Khazrai Y, Di Rosa C, et al. 2018. Study Design: Longitudinal Observational Study Country: Italy Funding Source: None reported	+	The purpose of this study was to evaluate the effectiveness of the intervention, diabetes conversation maps (CM) with a weight loss program, in achieving weight loss and the reduction of HbA_{1c} over the control, standard care with a weight loss program, in elderly Italians average age 67.8 (±7.93) years, with type 2 diabetes (T2DM), BMI > 25 kg/m^2.	This longitudinal observational study focused on elderly Italians average age 67.8 (±7.93) years, with type 2 diabetes (T2DM), BMI > 25 kg/m^2. The participants included 33 men and 33 women who were recruited by doctors and dieticians and could choose either the intervention (n = 32) or the control (n = 34).	Intervention: Conversation Maps (CM) with a weight loss program Pre-session: 15 min with a dietician at the beginning of each meeting evaluating the participants food diaries CM session: 75 min once per week for 4 weeks, all educators for these sessions were certified in CM CM educational method: 4 maps covering lifestyle changes, diabetes disease education, diet and exercise, and insulin use Control: Standard care with a weight loss program met initially, at 4 weeks, and at 3 months	Body Weight HbA_{1c}	Weight loss in the intervention ($p < 0.0001$) and the control ($p = 0.0078$) were significant at week 4, and there was a significant reduction in HbA_{1c} in the intervention ($p < 0.0001$) compared to control at 3-month follow-up
Author, year: Yeh et al., 2016. Study Design: Randomised controlled trial Country: USA Funding Source: NIDDK (1 R34 DK090695 and 5P60DK20541) and the National Center for Advancing Translational Sciences Clinical Translation Science Award, see article for all funding	+	The purpose of this study was to determine if the intervention, a culturally adapted diabetes prevention program (DPP), could achieve percent weight loss, reduced BMI, and reduced HbA_{1c} over the control, diabetes prevention materials, in prediabetic Chinese immigrants in New York city with an BMI ≥23 kg/m^2, HbA_{1c} 5.7–6.4%, averaged ages, control (60.9 ± 12.2 years) and intervention (56.8 ± 9.5 years).	This randomised controlled trial focused on 60 prediabetic Chinese immigrants in New York city with an BMI ≥23 kg/m^2, HbA_{1c} 5.7%–6.4%, averaged ages, control (60.9 ± 12.2 years) and intervention (56.8 ± 9.5 years). The participants were randomly assigned to either the intervention ($n = 30$) or the control ($n = 30$).	Intervention: Culturally adapted diabetes prevention program (DPP) for Chinese immigrants Sessions: 1.5 to 2 h, included materials in languages specific to the culture, exercises (tai chi), culture specific cooking tools, covering topics such as healthy eating and stress reduction Number of sessions: 12 bi-weekly core sessions with 6 monthly post-core sessions Program implementation: provided by trained lifestyle coaches Control: Diabetes prevention materials—mailed quarterly	Body weight/ maintenance HbA_{1c}	Weight loss at 6 months ($p = 0.0001$) and percent weight loss maintained at 12 months follow-up ($p = 0.0003$) as well a significant reduction in HbA_{1c} at 12 months follow-up ($p < 0.05$) in the intervention compared to the control

TABLE 3 (Continued)

Author, year, Study design, country, funding source	Quality grade (+, −, Ø)	Study purpose	Study population	Intervention and setting	Outcome measures	Results/Conclusion
Author, year: Bersoux et al., 2010. Study Design: Retrospective Analysis Country: USA Funding Source: None reported	+	The purpose of this study was to evaluate year 1 results of the six-month lifestyle intervention, the Diet-Exercise-Activity-Lifestyle (DEAL) program, in the reduction of body weight 7% and glucose in American adults who were referred to the study and had either impaired fasting glucose (IFG), impaired glucose tolerance (IGT), or IFG and IGT, but not type 2 diabetes (T2DM), average age 62 (±12) years.	This retrospective analysis focused on American adults who did not have type 2 diabetes (T2DM), average age 62 (±12) years. There were 114 referrals from clinics to the Diet-Exercise-Activity-Lifestyle (DEAL) program and 92 of those referrals had either impaired fasting glucose (IFG), impaired glucose tolerance (IGT), or IFG and IGT and were enrolled in the program ($n = 92$).	Intervention: Diet Exercise-Activity-Lifestyle (DEAL) program Primary emphasis: lifestyle change under 6 months Number of Sessions: initial visit, then four 2-h group classes with follow-ups at 6 and 12 months and a visit at 9 months if needed (the intervention occurred within 6 months) Sessions: provided by a nurse practitioner or a physician and physical therapists: covered nutrition and exercise Metformin: used post primary 6-month intervention if glucose levels/tolerance have not normalised or remained in pre-diabetic range Key focuses: lifestyle changes	Body weight/ maintenance	Weight loss ($p < 0.001$) and weight loss at 12 months ($p = 0.008$) in the intervention vs control group
Author, year: Yang et al., 2011. Study Design: Randomised controlled trial Country: USA Funding Source: Central Research Development Funds (CRDF) of University of Pittsburgh and the Montefiore Clinical Translational Research Center, see article for all funding.	+	The purpose of this study was to determine if the intervention, a 3-month yoga program, could reduce cardiometabolic risk factors including body weight over the control, general health education, in American adults ages 45–65 years old, with a family history of type 2 diabetes (T2DM), and have at least one cardiometabolic risk factor, do not or have not exercised (max: 30 minutes, 2 times/week), are at high risk for T2DM.	This randomised controlled trial focused on American adults ages 45–65 years old, with a family history of type 2 diabetes (T2DM), and have at least one cardiometabolic risk factor, do not or have not exercised (max: 30 min, 2 times/week), are at high risk for T2DM. The participants were randomised into either the intervention ($n = 13$) or control ($n = 12$).	Intervention: 3-month yoga program, lifestyle intervention Vinyasa style yoga: taught by certified instructor - PhD certified nurse Yoga session: 1-h long group sessions with a warm-up (5–7 min) and relaxation period (10 min) home practice was encouraged with audio instructions from instructor between group sessions along with maintaining any previous exercise habits Time frame: 2 times per week, 2–3 days between sessions Control: General health education packets mailed every 2 weeks for study duration covering topics like eating out along with maintaining any previous exercise habits	Body weight	Non-significant weight loss ($p = 0.166$) in mean weight change in the intervention versus the control

(Continues)

TABLE 3 (Continued)

Author, year, Study design, country, funding source	Quality grade (+, −, Ø)	Study purpose	Study population	Intervention and setting	Outcome measures	Results/Conclusion
Author, year: Farrer & Golley, 2014. Study Design: Non-randomised comparison Country: Australia Funding Source: None reported	+	The purpose of this study was to determine the effectiveness of the intervention, education, and very low-calorie diet (VLCD), in reducing body weight 5%–10%, HbA_{1c}, and cholesterol over the control, same education and meal plan, in Australian adults ages intervention (54 ±7.5) and control (57 ± 10.9) with type 2 diabetes (T2DM), BMI > 27 kg/m^2, raised cholesterol or blood pressure.	This small (n = 26) non-randomised comparison study focused on Australian adults ages intervention (54 ± 7.5) and control (57 ± 10.9) with type 2 diabetes (T2DM), BMI > 27 kg/m^2, raised cholesterol or blood pressure. The participants, guided by the program dietician using participants weight loss history, chose either the intervention (n = 9) if participants had a history of failed weight loss attempts or the control (n = 17) if participants had no history of weight loss attempts.	Intervention: Education and Optifast VLCD program Education: Number of sessions: 4 sessions total, once per month for 12 weeks, covering meal planning, eating out, and shopping Provided by: a dietician telephone support and weigh in (initiated by participant) Optifast VLCD program: 3 Levels: intensive (3 optifast/day + food for energy, no meals), transition (2 optifast/day + food for energy, some meals), maintenance (1 optifast/day + food for energy, more meals), at week 12 regular meals resumed Control: Same education program with a meal plan, telephone support and weigh in (initiated by participant)	Body Weight HbA_{1c}	Weight loss (p = 0.004) and significant in HbA_{1c} reduction (p = 0.017) in the intervention vs the control
Author, year: Franciosi et al., 2011. Study Design: Pilot randomised clinical trial Country: Italy Funding Source: None reported	+	The purpose of this study was to determine if the 6-month intervention, a self-monitoring and intensive education focused lifestyle intervention could achieve weight loss and reduction in HbA_{1c} < 7% compared to the control, standard counselling, in Italian adults with type 2 diabetes (T2DM), HbA_{1c} 7% - 9%, on oral hypoglycaemic therapy, and self-monitoring <1 time per week over the last 12 months, ages 45–75 years old.	This pilot randomised clinical trial focused on Italian adults with type 2 diabetes (T2DM), HbA_{1c} 7% - 9%, on oral hypoglycaemic therapy, and self-monitoring <1 time per week over the last 12 months, ages 45–75 years old. The participants were randomised by using a 3:1, intervention (n = 46) to control (n = 16), randomization ratio.	Intervention: 6-month self-monitoring and intensive education focused lifestyle intervention Number of sessions: one in—person session every 3 months and one phone call per month Standardised educational program: topics included estimating portion sizes, monitoring glucose, and diabetes related critical thinking Provided by: trained diabetes nurses Control: Standard counselling: follow-up visits every 3 months, focusing on lifestyle and diet	Body weight HbA_{1c}	Weight loss (p = 0.02) and reduction of HbA_{1c} (p = 0.04) in the intervention vs the control with 61.9% of the intervention group reaching HbA_{1c} of <7.0% at 6 months (p = 0.005) compared to the control

Note: ±6 of 8 < 12-month evidence-based lifestyle intervention programs (75%) resulted in significant reductions in weight, and/or HBA_{1c}, none found significant reduction in T2DM incidence.

efficacy of a 6-month self-monitoring and intensive education focused lifestyle intervention in Italian adults recorded significant reductions in weight loss ($p = 0.02$) and reduction of HbA_{1c} ($p = 0.04$) at month 6 in the intervention group compared to the control; furthermore, they found a significant portion (61.9%) of the intervention group reached the target HbA_{1c} of <7.0% at month 6 ($p = 0.005$) compared to the control (Franciosi et al., 2011). A smaller ($n = 26$) non-randomised comparison study evaluating the efficacy of an education and very low-calorie diet intervention in Australian adults found significant average weight loss ($p = 0.004$) and reduction in HbA_{1c} ($p = 0.017$) at 12 weeks in the intervention group compared to the control (Farrer & Golley, 2014).

Despite the positive findings noted above, a pragmatic cluster randomised controlled trial ($n = 1570$) evaluating the efficacy of a group education lifestyle intervention in South African adults did not find significant results in body weight loss ($p = 0.392$) or in the reduction of HbA_{1c} ($p = 0.967$) in either the intervention or the control group at a 12-month follow-up (Mash et al., 2014; Mash et al., 2015). Furthermore, an RCT evaluating the effects of a 3-month yoga program lifestyle intervention in American adults found slight but non-significant weight loss ($p = 0.166$) in the intervention group ($n = 13$) compared to the control ($n = 12$) at 3 months (Yang et al., 2011).

4 | DISCUSSION

The structure of the DPP study was used a guiding framework for some of the inclusion criteria in this review. Specifically the DPP's initial study timeline was the basis for determining this reviews program intervention duration of: ≥12-month, compared to <12-month programs. Likewise, the DDP acted as a guiding framework for many studies included in this comparative review, and it was used in a modified form or noted as an example for the framework by all five studies investigating ≥12-month interventions, one of which showed a partial or complete remission of T2DM is possible with lifestyle change (see Table 3). Four ≥12-month intervention studies used approaches adapted from the DPP focused on weight loss and physical activity and demonstrated that a 5%–10% weight loss and maintenance is statistically predictable in the age range defined by the review criteria. Only one of the included studies with a ≥12-month intervention focused on and was found to have a significant impact on HbA_{1c} values, adding to the evidence that the interventions based on the DPP and delivered ≥12 months may help reduce the risk of T2DM and/or prediabetes in adults aged 45 years and older (see Table 3).

Eight of the included studies had interventions <12-months (see Table 3). These studies were based on several different frameworks and were offered over a variety of durations <12-months. Additionally, these studies reported more issues than those interventions with durations over 12 months including six of the studies noted selection process issues and/or small sample sizes. Six of the eight included <12-month intervention studies found significant decreases in body weight. Also, six of the eight <12-month intervention studies evaluated HbA_{1c}, and five of those studies showed a significant reduction in HbA_{1c}. While all eight <12-month evidence-based lifestyle intervention studies evaluated at least one of the inclusion criteria outcomes, none of these studies evaluated as comprehensive parameters as the studies conducted ≥12 months; further evaluation of studies <12 months may contribute to the understanding of how intervention programs such as the ILI can reduce the development of T2DM and/or prediabetes within shorter durations (see Table 3). It must be noted that restrictive calorie diets are often not feasible for long durations and can lead to increased weight regain after cessation (Clifton, 2017; Paisey et al., 2002; Turk et al., 2009).

While the interventions included in this review reported significant outcomes associated with at least one of the parameters being investigated, future research will be needed to address the gaps in the literature that include using consistent indicators associated with reduction of pre-diabetes and/or T2DM, including more specific age ranges, and consistent study frameworks so it is easier to compare across studies. We recommend the use of categorical age ranges (e.g., 45–54, 55–64, 65+) to better understand efficacy associated with weight reduction over time, HbA_{1c} reduction over time, and prediabetes prevention. Results further defined via age stratification could lead to more tailored approaches when developing future nutrition education interventions.

A strength of this comparative review worth noting is that the 13 included studies had limited bias and all of these studies provided insight into the efficacy of possible reduction in the development of prediabetes and/or T2DM as related to the duration of lifestyle-based interventions; however, there were several limitations in this review.

Study limitations

Search bias may have been introduced by the incomplete retrieval of information due to human error in the search (see Table 1). Additionally, language bias is possible due to the search parameters being limited to articles only published in English. Furthermore, the inclusion/exclusion criteria notes that only studies with a less than 20% dropout rate were included in the review (see Table 2). One of the included <12-month studies had a higher dropout rate than the criteria (see Table 2); however, the framework, potential for study success, and the insight provided into the difficulties of using established methodology in an area with insufficient social and environmental support merited its inclusion into the review (Mash et al., 2014; Mash et al., 2015).

5 | CONCLUSION

Despite the consistent results and structured frameworks in the ≥12-month interventions, there is minimal evidence supporting a clear benefit of ≥12-month versus <12-month interventions in the

efficacy of normalising indicators of prediabetes or T2DM including 5%–7% weight loss and/or maintaining post-intervention weight loss, an $HbA_{1c} < 5.7$, and/or lowering incidence of prediabetes/T2DM. However, we found that evidence-based lifestyle intervention programs ≥12-months produced more consistent results related to prediabetes and/or T2DM than <12-month programs in adults aged 45 years and older. Additionally, there are benefits related to participation in lifestyle-based interventions based on known frameworks, including a reduction of risks related to prediabetes and T2DM, regardless of the duration of the intervention. Further research is warranted to better define the relationship between lifestyle intervention duration and intervention ability to modulate indicators associated with prediabetes and/or T2DM in more categorically specific age groups.

AUTHOR CONTRIBUTIONS

C.C. conceived and designed analysis. C.C., E.D., and B.A-E. collected the data and performed the analysis. J.B. and J.K. contributed data and analysis tools. J.B. and J.K. contributed. C.C. wrote the paper.

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None.

CONFLICTS OF INTEREST

No authors have any conflicts of interest to declare.

DATA AVAILABILITY STATEMENT

Data sharing is not applicable to this review.

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