Current Diabetes Reports (2019) 19: 43
https://doi.org/10.1007/s11892-019-1160-3

LIFESTYLE MANAGEMENT TO REDUCE DIABETES/CARDIOVASCULAR RISK (B CONWAY AND H KEENAN, SECTION EDITORS)

Diabetes Prevention Programs in Rural North America: a Systematic Scoping Review

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Published online: 19 June 2019

Abstract

Aims The aims of this systematic scoping review were to characterize the extent to which diabetes prevention programs have focused on rural populations in North America and where possible, identify efficacious program components.

Methods The review was guided by the PRISMA statement and five steps for scoping studies. Searches were conducted in August 2017 in Tucson, Arizona. Two teams of three independently screened full texts, excluding prior reviews, systematic reviews, and opinion pieces. Two authors abstracted data, which were reviewed by other team members.

Results Of the 12,840 articles identified, 12 met all criteria. Nine studies were based in the USA and three were Canadian. Demographics reflected high enrollment of underrepresented minorities, adults, and females. Methodological rigor was low; most studies were single-arm interventions evaluated using pre-/post-measures. Weight was measured across all studies, although biological, behavioral, and psychosocial outcomes were inconsistently assessed. Eight studies reported significant changes in primary outcomes. Duration and intensity were variable; delivery was led by trained volunteers or health professionals. Seven studies reported recruitment, retention, and adherence data.

Conclusions Surprisingly, few rural diabetes prevention studies have been published. Published programs were notable for lack of youth and/or family involvement, integrated prevention and treatment programs, and heavy reliance on self-reported outcomes.

Keywords Diabetes prevention · Rural health · Remote communities · Community interventions

This article is part of the Topical Collection on *Lifestyle Management to Reduce Diabetes/Cardiovascular Risk*

Electronic supplementary material The online version of this article (https://doi.org/10.1007/s11892-019-1160-3) contains supplementary material, which is available to authorized users.

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Introduction

Effective diabetes prevention remains a central public health challenge. Diabetes prevalence doubled over the past two decades, affecting 12.2% of US adults [1]. A majority of new cases are type 2 diabetes mellitus, a metabolic disorder characterized by defects in insulin action co-occurring with obesity [2]. Alarmingly, more than 84 million Americans have prediabetes [1], many of whom will progress to frank diabetes within the decade, jeopardizing their health and finances and drastically adding to healthcare costs [3]. Disparities in diabetes care exist for specific populations, including individuals living in rural and/or remote locations across North America who experience a 17% higher diabetes prevalence compared to urban dwellers [4•]. Provider shortages may contribute to frequent and significant challenges rural residents encounter when seeking care [5–7], further compounded by decreased access to medical facilities, parks, and grocery stores and fewer job opportunities and higher unemployment rates commonly experienced by rural residents [8].

It is well established that diabetes risk reduction is achievable with weight loss and lifestyle behavior modification. The Finnish Diabetes Prevention Study and the U.S.-based Diabetes Prevention Program both demonstrated reduced incidence with lifestyle modification and weight loss [9, 10]. Protective effects have persisted over time [11, 12]. Thousands of community prevention programs are now offered annually, bringing diabetes prevention within reach of thousands [13•]. However, it is unclear to what extent diabetes prevention has been made available to rural/remote-living individuals. Thus, we undertook a scoping study to map the literature on the particular topic of rural diabetes prevention, and identify key concepts, gaps in the research, and types and sources of evidence to inform future practice, policymaking, and/or research [14]. The purpose of this systematic scoping review was to characterize diabetes prevention programs delivered to rural populations and identify program components contributing to or detracting from their impact.

Material and Methods

The review was guided by the five steps for scoping reviews outlined by Arskey and O'Malley [15] and Levac et al. [16], as well as the methods for reviews described in the PRISMA statement [17].

Identification of Relevant Studies

Using controlled vocabulary terms (e.g., MeSH, EmTree) and keywords, a medical librarian (CLH) conducted searches in Ovid/MEDLINE, Elsevier/Embase, Elsevier/Scopus, Wiley/Cochrane Library, Clarivate/Web of Science (WOS), EBSCO/CINAHL, EBSCO/PsycInfo, EBSCO/ERIC, and ProQuest/Sociological Abstracts, from the databases' dates of inception to August 2017 (Appendix 1). All searches were completed on August 10 and August 11, 2017. Articles were also screened from reference lists of previous review articles related to the research questions and citations to and within the articles included in this review. No publication date or study type limits were applied. Only articles in English were considered.

Study Selection

Two teams of two individuals independently screened half of retrieved titles and abstracts. In cases of disagreement, team consensus was used for resolution. The two senior authors (MDH and VDS) independently screened the full texts selected in the title/abstract step. Articles were included if they met the following criteria: (1) program addressed diabetes prevention (and not only related conditions such as obesity or cardiovascular disease), (2) program was deployed in a rural area (programs with rural and urban components were included as long as rural data were separable from urban data), (3) study included outcomes, (4) published in English, and (5) conducted in the USA, Canada, or Mexico which were the regions of highest relevance to our own diabetes prevention work. Disagreements were resolved by consensus of the two senior authors. Previous reviews, systematic reviews, and opinion pieces were excluded. Database searches resulted in 12,840 publications with an additional 16 identified through citation analysis. Of the 6491 articles remaining after duplicates were removed, 6416 were found irrelevant at title/abstract screen and excluded (Fig. 1). The full texts of 75 articles were screened using full criteria outlined above, of which 12 met all criteria.

Charting the Data

Two individuals independently extracted the following from the twelve articles: first author, year of publication, study design, sample characteristics and setting, program characteristics, biomedical outcomes, behavioral and knowledge outcomes, and process evaluation outcomes. These data were summarized and reviewed by two other individuals who confirmed the accuracy of each entry, and independently reviewed by one of the senior authors (MDH) who resolved discrepancies. A summary of the data extracted from the twelve included articles can be found in Appendix 2.

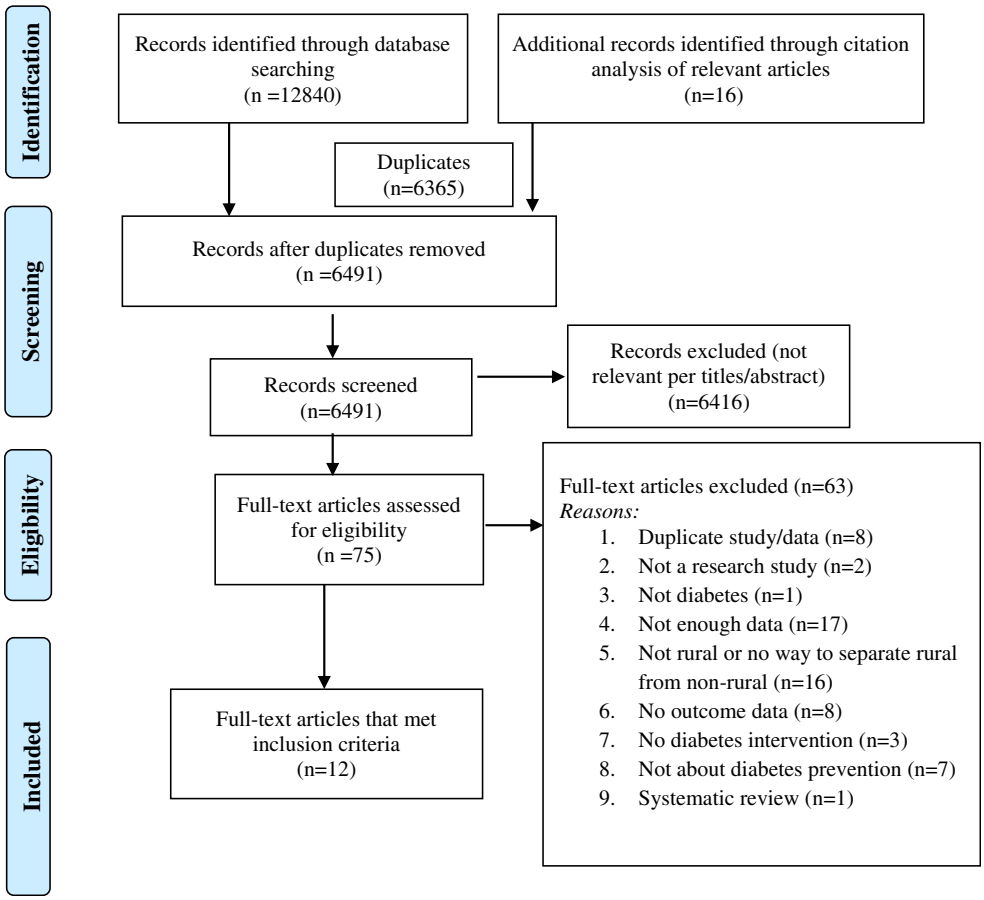

Fig. 1 Literature search and extraction of studies meeting inclusion criteria

Results

Publication Descriptions

Nine studies took place in the USA [18–26] and three in Canada [27–29]. Demographics varied widely. Study-reported ethnicities of participants were as follows: three studies enrolled African Americans [18, 20, 21], two American Indian [19, 23], and one each reported enrolling Aboriginal [27], First Nation [28], Hispanic [24], and Mohawk [29] populations, respectively. Three studies did not specify study racial/ethnic composition [22, 25, 26]. Although one study intentionally recruited female participants [18], most studies did not specify sex as an inclusion criterion. Of those eleven studies that included both sexes, four did not report the proportion of female to male participants [19, 20, 27, 29], one study reported majority male participants [23], and six reported predominantly female participants [21, 22, 24–26, 28]. Eight studies focused on adults [18, 20–22, 24–27], three enrolled only youth [23, 28, 29], and one enrolled both [19]. Participants ranged in age from 5- to 81-years-old.

Research designs varied greatly. Seven out of twelve studies utilized quasi-experimental designs with a single intervention arm and pre-/post-measurements [20, 22–25, 27, 28]. Additional designs included a two-cluster randomized controlled trial [18], a qualitative study [19], community-based participatory research [21], and, as described by the authors, a mixed cross-sectional and longitudinal study design with a non-equivalent comparison group [29]. Six of the 12 studies examined an intervention with a comparison group(s) [18, 24, 26–29]; two of these studies used another intervention as the comparison [18, 26].

Program intensity and duration also varied greatly. Five programs met weekly for 3 weeks [25], 7 weeks [24], 16 weeks [26], 5 months [28], and 18 months, respectively [18]. Boltri et al. held weekly meetings but separated participants into two groups of varying duration (6- and 16-weeks) [20]. In another study, participants met up to four times per week for 4 or 8 weeks [22]. Three studies specified core intervention duration (7 weeks [24], 24 months [27], or up to 3 years [19]) but not frequency. A youth study required ten classroom lessons per academic year [29]. Six of twelve studies followed participants after the core intervention for about 6 months or less [18–20, 23, 25, 26].

Program Characteristics

Three studies enrolled individuals diagnosed with type 2 diabetes [21, 23, 27], four excluded individuals with type 2 diabetes [18, 20, 25, 26], and five did not specify type 1 or type 2

diabetes as an exclusion criterion [19, 22, 24, 28, 29]. All except one program [23] used group-based program delivery. Settings included community centers [21, 22, 27], schools [19, 28, 29], churches [19, 20], homes [23, 24], worksites [19], a hospital [26], and a primary care office [25]. One study did not specify setting [18]. Programs were delivered by researchers [18], community health workers [23, 24, 27], trained volunteers [22], peer mentors [21, 28], classroom teachers [29], healthcare professionals [20, 25, 26], or a combination [19].

Study Outcomes

Study outcomes were inconsistently collected and reported by article authors. Herein, we summarize outcomes as described by study authors, including: anthropometric outcomes (body weight or body mass index, waist circumference, skinfold thicknesses, or percent fat assessed using bioelectrical impedance; blood pressure; blood glucose or glycated hemoglobin A1c; lipids); behavior and knowledge outcomes (physical activity, psychosocial outcomes, diabetes and diabetes-related knowledge, dietary behaviors and adequacy); and program evaluation outcomes (recruitment, retention, and adherence). Additional details can be found in Appendix 2, Summary Table of Included Studies.

Anthropometric Measures

Body weight and/or body mass index (BMI) were measured in all studies, waist circumference in three studies [18, 23, 28], skinfold thickness in one study [29], and percent fat in one study [19]. Of eight studies measuring body weight [18–21, 24–26, 29], three reported statistically significant decreases at follow-up [18, 20, 25]. In their 24-month randomized controlled trial of an evidence-based behavioral weight loss program in African American women living in the rural South, Ard et al. observed -2.7 ± 4.6 kg ($p < 0.001$) and -1.9 ± 3.9 kg ($p < 0.001$) changes in the weight loss and weight loss "plus" groups, respectively, at 6-month follow-up, but no differences were observed between groups [18]. Boltri et al. conducted a small group-based pilot study testing two program durations (6-week and 16-week) in five African American churches in rural communities in Georgia, observing a −1.7-kg weight decrease post-intervention ($p = 0.008$) across groups, but not at 6 and 12 months [20]. Straight reported a statistically significant decrease in body weight between baseline (221.1 lb) and 9-week post-intervention measures (211.1 lb, $p = 0.000$) in a primary care-based pilot with 25 participants identified via the medical record as at risk of Type 2 diabetes [25]. Vadheim et al. conducted simultaneous face-to-face and virtual versions of the same intervention, noting that across these delivery methods, 56% achieved > 5% body weight loss at follow-up (no differences between groups) [26]. Two of the eight studies assessing body weight did not test whether weight loss at follow-up was significantly different than baseline [19, 24], while two other studies stated that body weight was measured but did not report specific data [21, 29].

Two faith-based diabetes prevention programs, Ard et al. [18] and Boltri et al. [20], both reported significant decreases in BMI consistent with decreases observed in participant body weight. Daniel et al. observed a significant differential change in BMI between intervention and control communities at 16 months (intervention, 30.8 kg/m^2; 95% CI 29.3–32.3 kg/m^2 to 30.4 kg/m^2; 95% CI 28.9–31.8 kg/m^2, and control, 27.5 kg/m^2; 95% CI 25.8–29.2 kg/m^2 to 28.6 kg/m^2; 95% CI 26.8–30.3 kg/m^2, $p = 0.004$) [27]. Straight observed a significant decrease in BMI at the 9-week follow-up in 25 participants (35.3 kg/m^2 to 33.5 kg/m^2, $p = 0.000$) [25]. Millard et al. reported significant decreases in BMI in the intervention group (31.9 kg/m^2 ± 6.16 to 31.7 kg/m^2 ± 6.08; $p = 0.005$) relative to the comparison group [24] following the 8-week group-based promotora (community leader)–led intervention. Drozek reported a 3.5% post-intervention decrease in BMI in 225 participants ($p < 0.001$) [22]. Of the three remaining adult-focused studies, one did not observe significant changes in BMI [26], one did not formally test change in BMI [19], and one did not report BMI outcomes [21]. Three youth-focused studies also assessed BMI. One study reported a significant BMI z-score at 6-month and 12-month follow-up (2.19 ± 0.04 to 2.17 ± 0.04, $p = 0.024$, and 2.19 ± 0.04 to 2.16 ± 0.04, $p = 0.004$, respectively) [23]. A second study in youth reported greater attenuation in BMI z-score in intervention participants (−0.05; 95% CI, −0.11 to 0.002) compared with control (0.04; 95% CI, −0.001 to 0.08) at 5 months ($p < 0.01$) [28]. A third youth study reported increased BMI in both intervention and comparison groups [29].

Two of three studies assessing waist circumference showed significant post-intervention decreases [18, 28]. In their 24-month cluster randomized trial testing the efficacy of an evidence-based behavioral weight loss program with (enhanced) or without the addition of funding for community resources supporting healthy eating or physical activity (e.g., community garden, walking trails), Ard et al. observed decreased waist circumferences in both intervention groups at 6 months, although mean reduction was greater for the enhanced (weight loss plus) intervention group (−2.9 cm ± 8.5) versus the weight loss only group (−1.2 cm ± 6.2) [18]. In youth, Eskicioglu et al. observed a significantly smaller change in intervention participants (+0.34 cm; 95% CI, −0.96 to 1.64) compared to control (+2.87 cm; 95% CI, 1.92 to 3.82), $p < 0.01$ [28]. Kenney et al. did not find significant changes at follow-up [23]. A single study by Paradis et al. measured subscapular and triceps skinfold thickness in youth, finding smaller increases in subscapular and triceps skinfold thicknesses in intervention community youth versus control communities [29]. Bachar et al. reported that participant body

fat "was reduced" in the worksite wellness program but did not provide data [19].

Blood Pressure

Eight studies measured blood pressure [18, 20–23, 25–27]; four studies reported significant decreases in systolic blood pressure (SBP), diastolic blood pressure (DBP), or both [18, 22, 25, 27]. Ard et al. reported a decrease in both intervention arms (behavioral weight loss only, SBP: −1.9 mmHg ± 11.0, $p < 0.04$; DBP: −1.7 mmHg ± 8.3, $p < 0.04$; and behavioral weight loss plus community strategies, SBP: −4.0 mmHg ± 14.5, $p < 0.001$; DBP: −2.9 mmHg ± 9.1, respectively, $p < 0.001$) [18]. Drozek et al. found significant decreases in SBP (−4.7%, $p < 0.001$) but not DBP (−1.7%, $p = 0.085$) [22]. Similarly, Straight also observed significant decreases in SBP from the baseline mean of 130.2 mmHg to post-intervention (9-week) measure of 125.6 mmHg, $p = 0.04$ [25], but no significant changes in DBP. Daniel et al. reported a significant differential change in SBP between the intervention community and control communities (intervention, 121.5 mmHg; 95% CI 113.0–130.0 mmHg to 115.5 mmHg; 95% CI 109.4–121.6 mmHg, and control, 113.3 mmHg; 95% CI 105.8–120.8 mmHg to 118.8 mmHg; 95% CI 110.6–127.0, $p = 0.017$) but did not present DBP data [27]. Two studies showed no changes in blood pressure [20, 21]. One study described blood pressure measurement but did not report outcomes [26]. A youth-focused study found a significant decrease in the proportion of youth with SBP or DBP ≥ 90th percentile for sex and age at 12 months (32.6% at baseline, to 24.2% at 12 months, $p = 0.002$) [23].

Blood Glucose and Glycated Hemoglobin A1c (HbA1c)

Fasting blood glucose was measured in six studies [18, 20–22, 25, 26]. Drozek et al. reported a 4.1% mean decrease in fasting glucose in 225 adults ($p < 0.001$) [22], while Straight reported a significant decrease in fasting glucose between baseline and post-intervention (115.3 to 98.1 mg/dL, $p = 0.000$) [25]. Boltri et al. reported a post-intervention decrease in fasting blood glucose in 37 individuals (108.1 to 101.7 mg/dL, $p = 0.037$) [20]. One study observed no significant changes in blood glucose [18], while two others described measurements but did not report data [21, 26]. Glycated hemoglobin (HbA1c) was measured in two studies [23, 27]. In one, an increase in HbA1c was observed in the intervention community relative to control communities [27]. A study in youth reported a decrease in HbA1c at 6 months among a subset of 29 diabetic youth [23].

Lipids

Total cholesterol (TC), high-density lipoprotein (HDL), low-density lipoprotein (LDL), and triglycerides (TG) were measured in four studies [18, 22, 25, 26]. Vadheim et al. described lipid measurement but did not report data [26]. Straight reported improved lipid profiles, although changes were not statistically significant [25]. The remaining two studies had mixed results. Drozek et al. observed clinically significant decreases in lipids at 16-week follow-up for TC (−10.3%, $p < 0.001$), HDL (−10.2%, $p < 0.001$), and LDL (−10.3%, $p < 0.001$) but no significant changes in triglycerides [22]. Ard et al. reported a significant decrease in TG in both intervention arms (−10.7 ± 62.0 mg/dL, $p < 0.04$, and −22.1 ± 95.0 mg/dL, $p < 0.001$, respectively) but no changes in TC or HDL to LDL ratio in 409 participants at 18 months [18].

Physical Activity

Seven studies assessed physical activity (PA) and/or physical fitness, all of which found improvements [19, 21, 23, 24, 26, 27, 29]. Cene and colleagues collected self-reported PA intensity and frequency from adult African American participants living in rural, low socio-economic status counties in North Carolina after their feasibility study, noting improvements that were not statistically significant [21]. Daniel et al. assessed self-reported frequency of "sweat-producing physical activities" in participants from a single intervention and two comparison Canadian Aboriginal communities, observing a decrease in the intervention group, but not controls [27]. In a community-wide diabetes prevention intervention, Bachar et al. described an increase in self-reported PA in workplace-, school-, and church-based intervention groups evaluated through personal interviews and "other" (not described) methods, but did not report specific data [19]. In a study comparing face-to-face with telehealth-delivered versions of the intervention, Vadheim et al. found that participants in both study arms exceeded the weekly PA goal of ≥ 150 min (167.4 and 182.0 min, respectively); there were no significant differences between these groups [26]. In their mixed cross-sectional and longitudinal study with non-equivalent comparison groups, Paradis et al. assessed PA using a 7-day recall (completed by parents if the child was younger than fourth grade), finding a 23% increase in the frequency of self-reported 15-min bouts of PA each week in intervention and control communities over 2 years; specific to the intervention community, they also observed decreased weekly gym class frequency and a 22% decrease in performance on the run/walk fitness test [29]. Sedentary behavior was also assessed in this study, using frequency of television/video watching on weekdays and Saturdays as a proxy measure; in the intervention group, self-reported television watching during the school week decreased (but this was not statistically significant),

and there was no self-reported change in Saturday television watching [29]. Kenney and colleagues evaluated PA in American Indian youth from four tribal communities in the Southwestern United States using a 3-day recall, finding that 32% of participants were active one or more days at baseline, and that this proportion increased to 38.9% at 6 months and to 49% at 12 months [23]. Millard et al. asserted that PA was incorporated into the 7-week intervention with primarily Mexican immigrant participants living at the Mexico-Texas border, but did not report related assessment methods or outcomes [24].

Psychosocial Outcomes

Six studies evaluated psychosocial outcomes [19, 21, 23, 25, 27, 28]. Bachar et al. reported that students receiving mentoring at school reported increased interest in learning (82.1% versus 43.8%) and their ability to easily interact with friends (66.7% versus 53.6%) [19]. Kenney et al. assessed quality of life using the PedQl and found significant improvements at 6 months ($p < 0.001$) and 12 months ($p < 0.001$) [23]. Three studies evaluated self-efficacy [23, 25, 28]. Straight reported significant increases in self-efficacy for "eating more healthy food" and "overeat less often" [25]. Kenney et al. examined perceived ability to achieve goals and cope with life challenges using the 5-item Communal Family Mastery Scale but did not report outcome data [23]. Eskicioglu et al. evaluated youth self-efficacy but did not specify methodology or provide data [28]. Cene et al. evaluated self-reported goals and expectations about diabetes prevention in 104 African American participants but saw no significant changes after the 8-month intervention [21]. Daniel et al. assessed self-esteem, depression, affect balance, mastery and social support, and quality of life but did not report those data [27].

Diabetes and Diabetes-Related Knowledge

Three studies assessed diabetes knowledge and all reported post-intervention gains [21, 23, 27]. Two hundred fifty-six youth (10- to 19-years-old) were evaluated on their knowledge of nutrition, PA, and diabetes prevention and management in a survey created by the authors, who found significantly higher scores at 6-month ($p < 0.001$) and 12-month follow-ups ($p < 0.001$) [23]. In 104 African American adults, Cene et al. observed significant increases in diabetes knowledge (64% versus 80% correct on a questionnaire, $p < 0.01$) at 6 months [21]. Daniel and colleagues also evaluated diabetes knowledge in 105 adults using a 13-item questionnaire, finding no changes in score in the intervention group, while the comparison group decreased from baseline [27]. Bachar et al. reported increased interest in health and diet-related books and knowledge related to healthy food choices by fourth- to sixth-grade students but did not provide data [19]. Eskicioglu et al. evaluated knowledge of healthy foods and PA in youth, finding significant increases in food knowledge in the intervention arm but no differences in PA knowledge [28].

Dietary Behaviors and Adequacy

Seven studies assessed dietary quality, dietary behaviors, and nutrition adequacy [19, 23–27, 29]. Straight evaluated dietary changes in 20- to 60-year-olds using self-administered surveys, finding a majority of participants reported reduced frequency of overeating and consumption of high-fat food [25]. Paradis et al. used an adapted 7-day FFQ inclusive of foods common to the Mohawk community and found no significant dietary changes in sugar, fat, fruit, and vegetable consumption in 6- to 11-year-olds [29]. A separate study in 10- to 19-year-old American Indian youth evaluated dietary changes using an adapted Block FFQ, finding no changes in fats and sweets, and significantly decreased consumption of fruit servings (1.26 vs 1.04, $p < 0.001$) and grain servings (6.11 vs 4.77, $p \leq 0.001$) at 12 months [23]. Four other studies reported changes in dietary behaviors but did not report results [19, 24, 26, 27].

Program Evaluation Outcomes: Recruitment, Retention, and Adherence

A priori recruitment goals were specified in four of twelve studies [20, 21, 23, 25]; three of these met their goals [20, 21, 23]. Seven studies [18, 19, 22, 23, 25, 27, 28] reported retention rates ranging from a low of 42.2% [27] to a high of 99.5% [18]. The definition of retention varied considerably among these seven studies. Ard et al. reported that 99.5% of participants completed the study although considered participants completers even if follow-up measurements were not obtained [18]. Bachar et al. reported that 85 of 86 individuals participated in their worksite wellness program for 1 year [19], while Drozek et al. reported that 210 of 225 participated in all aspects of the study but did not describe what participation entailed [22]. Straight reported 100% adherence, wherein 25 participants completed the three required sessions and assessments [25]. Three remaining studies assessing retention [23, 27, 28] did not specify the proportion of participants retained, but mentioned they took part in "at least some" data collection. Seven studies defined participant adherence as attendance at intervention sessions [18, 20, 21, 23–26]. Three of these studies reported the mean number of sessions attended: Straight reported 100% adherence to all three classes [25], Boltri et al. reported 68.7% attendance at the 6-week intervention and 56.6% at the 16-week intervention [20], and Ard et al. reported an average of 10.6 of 20 sessions for the "weight loss only" intervention arm and 12 of 20 sessions for "weight loss plus intervention" arm [18]. Two studies defined specific cut

points as "adherent"—Cene et al. [21] reported 43% of participants attended ≥ 75% of the sessions, while Vadheim et al. [26] used CDC's definition for diabetes prevention programs [13•], and reported 98% of telehealth and 96% of face-to-face attended 9+ sessions in the first 6 months and 3+ sessions in the last 5 months. Five studies did not report adherence data [19, 22, 27–29].

Discussion and Conclusions

The purpose of this scoping review was to describe the landscape of rural diabetes prevention efforts in North America, specifically, the extent to which diabetes prevention programs serve rural populations, and to summarize existing data for use by practitioners, researchers, and health professionals seeking to make an impact on rural diabetes prevention. Where possible, we sought to evaluate the program characteristics that may have contributed to or detracted from reach and impact.

Included studies were notable for offering diabetes prevention and treatment within single programs, rather than simply focusing on prevention. This was very likely a function of community size, wherein by virtue of their low population, rural/remote communities also have low numbers of individuals at risk or with diabetes, and limited resources necessitate combining programs for efficiency and cost containment. There was also a lack of programs for youth and families. There are many possible reasons for this. As with adult programs, this could reflect the availability of human and other resources. Type 2 diabetes prevalence is higher in adults than youth, and limited resources are directed at the greatest need. Youth- and family-focused programs require program leaders with different skill sets than adult programs; engagement and retention strategies also differ slightly, and rural communities may not have leaders with specific expertise. It was notable that the youth-focused programs in this review did not directly engage parents or caregivers, which has been identified as a critical "ingredient" of youth interventions. Studies of children with diabetes have reported that parents often struggle to help their children manage their disease [30]. Thus, providing parents with the support and strategies needed to positively influence child health and serve as a role model is a critical and often missing component of youth-focused prevention, regardless of geographical location.

This review aimed to identify real-world implementation of diabetes prevention programs in rural areas. Twelve studies were identified through this literature review, which were far fewer given the expansive scope of the general diabetes prevention literature. A potential limitation of our search was its constraint to the published literature, which likely does not reflect the entirety of diabetes prevention programs offered in rural/remote areas, particularly those in tribal lands. The paucity of programs in the academic literature presents an opportunity for researchers to partner with local organizations to rigorously evaluate and communicate findings of diabetes prevention programs in rural areas. One potential such partnership is with the nationwide Cooperative Extension informal education network, which serves as the community outreach arm of all US-based land grant universities [31]. Charged with bringing evidence-based programs to solve problems and improve lives in local communities, Extension is strategically positioned to support diabetes prevention in rural/remote regions. Indeed, Extension faculty in more than a dozen US states are already offering diabetes prevention programs through Extension networks [13•]. Partnerships between public health researchers, Extension, and community stakeholders will serve to strengthen a growing evidence base in implementation and dissemination research and ensure programs reach those who have the greatest need.

This review also sought to identify specific program elements or factors that led to successful outcomes in diabetes prevention programs in rural areas. A lack of data and details in the included studies prevented us from systematically evaluating program characteristics contributing to, or detracting from, program reach and impact. The included studies reported limited to no impact on biomedical risk factors such as BMI and blood glucose, and behaviors such as physical activity and healthy eating. In part, this may have been due to the methodologies selected to capture these outcomes (largely self-report), intensity of the intervention (most programs fell short of evidence-based and expert recommendations [32, 33]), and lack of consistent outcomes reporting in the publications. Where available, many outcomes were not reported in terms of statistical or clinical significance, nor indicated direction or magnitude of effect. Process and program outcomes were also lacking, with few details on strategies used to recruit, retain, and engage participants. Study authors had few suggestions for what could be done to improve engagement and impact.

Future research on diabetes prevention programs in rural communities should consider unique challenges faced by rural populations, and how they might differ from challenges experienced by individuals living in more populated areas. Flexible, accessible, and low-cost programs remain a critical need for often geographically isolated individuals who may also lack the financial resources and transportation infrastructure to participate in traditional, intensive, face-to-face diabetes prevention programs [7].

In summary, there is a great need for rigorous development, implementation, and evaluation of diabetes prevention programs in rural areas. Understanding the extent and efficacy of programming designed for and available to rural and remote areas remain critical and open research questions. Strategic partnerships with community stakeholders can help ensure that existing evidence-based programs are appropriately adapted to fit the needs of rural populations, and that new programs are designed from the

outset to respond to the needs and challenges of these communities.

Compliance with Ethical Standards

Conflict of Interest The authors declare that they have no conflict of interest.

Human and Animal Rights and Informed Consent This article does not contain any studies with human or animal subjects performed by any of the authors.

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Papers of particular interest, published recently, have been highlighted as:
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