

REVIEW ARTICLE



Preventing type 2 diabetes among Indigenous youth: A systematic review of community-based interventions

Shelley Spurr ^a, Meridith Burles ^a, Shannon Hyslop^a, Jill Bally^a, Carol Bullin ^a, Amanda Froehlich Chow ^b, Helen Tootoosis^c and Sarah Oosman^d

^aCollege of Nursing, University of Saskatchewan, Saskatoon, Saskatchewan, Canada; ^bSchool of Public Health, University of Saskatchewan, Saskatoon, Saskatchewan, Canada; ^cIndigenous Liaison Advisor for Saskatchewan, Statistics Canada, Saskatoon, Saskatchewan, Canada; ^dSchool of Rehabilitation Sciences, University of Saskatchewan, Saskatoon, Saskatchewan, Canada

ABSTRACT

A systematic review was conducted to assess evidence on effectiveness of community-based interventions promoting wellbeing and prevention of type 2 diabetes (T2D) among Indigenous youth. A convergent, segregated, mixed methods approach was used, with six databases and four grey literature sites searched from inception to May 2022. Articles selected for inclusion were about community-based interventions related to T2D prevention with Indigenous youth that evaluated effectiveness or youth experience published in English. Reference lists were also searched for relevant sources. Seven quantitative research articles met the inclusion and quality assessment criteria. No qualitative articles were identified. The results were synthesised through narrative analysis, while meta-analysis was not possible due to heterogenous study designs. Common foci across interventions included promoting physical wellness, improving physical activity and healthy eating patterns, enhancing knowledge, and psychosocial wellness. Interventions deemed effective addressed multiple areas, were school-based, and operated for at least a year. Findings support multi-strategy, community-based interventions implemented over longer periods of time. However, gaps in research and reporting included the extent to which interventions are culturally informed and based on community-driven priorities. Future research should include Indigenous, mixed and qualitative methods and Indigenous-driven measures of success to better understand effectiveness in alignment with Indigenous worldviews.

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Evidence indicates that there are increasing rates of type 2 diabetes [T2D] among youth in Canada and beyond [1–4]. In particular, there are disproportionately high rates of T2D among Indigenous peoples including First Nations, Métis and Inuit youth in Canada [5], which are anticipated to rise if left without meaningful intervention. Due to complex factors arising from colonialism and ongoing social and health inequities [5], an estimated 44% of new cases of young-onset T2D diagnosed in individuals under 18 years of age in Canada will be among Indigenous children and youth [6]. T2D incidence is especially high in the Prairie provinces. In Manitoba, where research on paediatric T2D has been extensive, incidence is reported to be 12.45 cases per 100,000 [6]. While reliable province-wide statistics are not available for Saskatchewan, research with three Indigenous communities found that approximately 10% of youth participants had elevated blood

glucose levels, and 73% of youth participants had two or more risk factors for T2D [7]. In the United States, disproportionate rates of T2D are also reported among Indigenous peoples [8]; a large multi-centre study reported 46.5 cases per 100,000 in Native American youth aged 10–19 years compared to 12.5 cases per 100,000 in the broader sample [9]. Earlier or “young-onset” of T2D is associated with more advanced disease and greater complications than onset later in adulthood [10,11] which will impact quality of life and ageing-related functional decline across the lifespan. Given the preventable nature of T2D, it is imperative to address the inequitable rates and disproportionately negative outcomes among Indigenous youth, with an emphasis on ways that are driven by Indigenous worldviews. While various initiatives are required to address social and health disparities broadly, it is beneficial to identify community-based approaches to health promotion

CONTACT Shelley Spurr  Shelley.spurr@usask.ca  College of Nursing, 107 Clinic Place, University of Saskatchewan, Saskatoon, Saskatchewan S7Z 2Z4, Canada

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with Indigenous youth that have been effective in preventing or, at minimum, delaying the onset of this chronic and potentially severe condition.

Historical context of Indigenous health and wellness

Disproportionate rates of T2D among Indigenous youth can be understood relative to a complex interplay of historical, social, political, economic and geographic factors that have produced social and health inequities [5,12,13]. Foremost, lasting impacts of colonisation have created environmental, social, political and economic conditions that contribute to compromised health and wellness and increased risk for development of T2D [5,6,14,15]. For instance, the Canadian Government implemented the reservation system and related policies that imposed a loss of agency and restricted the movement of many Indigenous peoples, leading to decreased engagement in land-based activities and a more sedentary way of life than traditionally [14,16]. Additionally, Indigenous peoples living on reserve often face sub-standard living conditions, environmental exposures, food insecurity, unemployment and poverty along with inadequate access to resources and health care services [5,15], which compromise health and wellness. Colonial policies have also included bans on cultural ceremonies and steps to assimilate Indigenous children through residential school attendance or placement in non-Indigenous families. Resultantly, many Indigenous peoples have experienced personal and intergenerational trauma, cultural dispossession, breakdown of kinship ties, dissolution of traditional ways of living and loss of language and intergenerational teachings including those related to land-based nutritional knowledge and practices, all of which have significant impacts on health and wellness [14]. Ongoing systemic discrimination and social marginalisation continue to impact many Indigenous peoples in Canada and the United States, contributing to compromised physical and mental health [8,15]. Accordingly, understanding the disproportionate rates of T2D among Indigenous peoples, and youth specifically, requires acknowledgement of the interplay of historical and contemporary social determinants that affect opportunities for health and wellness at the individual, community and system levels [17,18]. Such recognition can foster multi-level efforts that identify system-level barriers to wellness and prioritise community-driven health promotion and decolonised research aimed at addressing profound health inequities.

Community-based interventions with Indigenous peoples

Increasing attention to the broader context of Indigenous peoples' health is evident in efforts over recent decades to attend to social, cultural, historical and structural factors within behavioural and educational T2D prevention and management interventions. As Crowshoe et al. [5] emphasise, it is essential to account for the social contexts that influence Indigenous peoples' health, as solely attending to behavioural change is not sufficient. Accordingly, development of programmes and interventions has been undertaken through engagement with specific communities to promote cultural relevance and appropriateness of lifestyle interventions. Several interventions and programmes also address structural barriers to health (such as food insecurity) and promote improved social supports, along with enhancing T2D knowledge and practices. For instance, in Canada, initiatives in the Mohawk community of Kahnawake [19], the Oji-Cree community of Sandy Lake [20] and the Métis community of Île-à-la-Crosse [21] arose from community engagement and a foundation in local priorities and values.

A recent systematic review by Kurtz et al. [13] documents several culturally relevant interventions related to diabetes and obesity across Australia, Canada, New Zealand and United States, while two scoping reviews by Vincze et al. [22] and Bonin et al. [23] examine cultural adaptation of nutritional components of health interventions conducted with Indigenous peoples and management practices incorporating traditional Indigenous approaches for people living with T2D, respectively. The interventions described were implemented with adults, adults and children, youth, families and/or whole communities, and varied in length, activities and evaluation, with the majority including behavioural and educational components related to exercise and diet. Cultural adaptation involved inclusion of traditional foods and Indigenous languages, along with input from, and delivery by, community members [22]. Additionally, many culturally relevant interventions addressed holistic health through inclusion of cultural, spiritual, emotional and psychosocial elements in conjunction with intergenerational approaches [13]. Most interventions were deemed successful in enhancing health and wellness due to inclusion of cultural components across the trajectory that generated a sense of togetherness with family, community and culture; promoted personal and community empowerment; and engaged with local Indigenous culture and traditions [13]. Traditional Indigenous approaches to interventions

and programming included storytelling, talking circles, feasting, prayer, dancing, hunting and school-based wellness curricula. These activities were holistic, co-created with community, Indigenous-led, and held in the community [23]. Therefore, the findings of these reviews indicate that culturally informed and adapted interventions can be effective either on their own or alongside Western interventions [13], with greater meaning and impact arising from interventions that are Indigenous-led or co-designed [22].

Accordingly, existing community-based, culturally relevant interventions highlight possibilities for addressing the inequitable rates and impacts of T2D in Indigenous peoples. The literature on such T2D-related interventions is quite disparate, however, making more focused review and synthesis essential. Efforts are needed to identify the specific nature of the interventions carried out with Indigenous youth as adolescence is a pivotal time in which health promotion efforts can prevent or delay T2D and minimise adverse outcomes associated with early onset [10]. Furthermore, because evidence suggests that some existing interventions do not resonate with youth or bring about the anticipated outcomes [2,18], there is a need to critically appraise interventions specific to Indigenous youth aged 13–19 years to understand their characteristics and context. It is also important to examine how specific interventions have been evaluated for effectiveness and identify beneficial outcomes for Indigenous youth. Such efforts should distinguish research focused on youth diagnosed with T2D or pre-diabetes from those without such diagnoses, with the aim to determine promising strategies for the prevention or delay of onset of T2D specifically.

Purpose

To build upon and expand current knowledge, we systematically examined existing community-based interventions among Indigenous youth, evaluation methods and outcomes to identify key findings that can direct future health promotion and prevention efforts. This review of the current intervention literature also highlights successful outcomes arising from community-based research and areas for decolonised approaches to, and enhancement of, future interventions and programmes. This systematic review was guided by the overarching research question and sub-questions: What Indigenous community-based interventions promote wellbeing before diagnosis of T2D among youth? What Indigenous community-based interventions are effective for preventing diagnosis or delaying the onset of T2D among youth with and without their families? What are the experiences of Indigenous youth with community-based interventions aimed at preventing

diagnosis or delaying the onset of T2D? Focus on the effectiveness of existing interventions and Indigenous youths' experiences was chosen to ensure a broad scope for evaluation of existing literature, allowing for inclusion of quantitative, qualitative and mixed methods research. This approach was informed by Ermine's concept of "ethical space" to promote the engagement of Indigenous knowledge and Western science as equally valid but diverse forms of knowledge that can generate new understandings and solutions [24].

Materials and methods

The Joanna Briggs Institute (JBI) Manual for Evidence Synthesis guided the research team in conducting this mixed methods systematic review (MMSR) [25]. The review was carried out by multidisciplinary researchers from the disciplines of nursing, health sociology, public health, physiotherapy and a Cree Knowledge Keeper. Members of the team have extensive research experience, including conducting systematic reviews and community-engaged research[26][27][28]. Additionally, the team is being guided by a broader network of Knowledge Keepers, clinicians and Indigenous community members with lived experience of diabetes. The larger network was engaged in discussions that informed the review process, while the co-authors were involved in carrying out the steps in the review and synthesis process. Engagement with Indigenous team members and communities is part of a larger multi-phase research project that is based on the Memoranda of Agreement with community partners and ethical approval from the researchers' academic institution.

Search strategy

The search strategy included exploration of six online databases (CINAHL, Cochrane, Embase, MEDLINE, PsycINFO and Web of Science) and grey literature searches. The PICO framework structured the overarching research question and associated search terms. The research team and members of a larger research network made up of Indigenous Knowledge Keepers who are recognised holders of cultural knowledge within their communities, adults and youth with T2D lived experiences, and clinicians contributed to the development of the research questions and keywords. These discussions were part of the first phase of a multi-phase community-engaged research project being guided by the research network and community partners. The primary search terms were: (Indigenous, Aboriginal, Native, Indian, First People, First Nations, Métis, Inuit), and (Type 2 diabetes, Type 2 diabetes mellitus, non-insulin dependent diabetes mellitus, non-insulin dependent diabetes, diet control diabetes, pre-diabetes), and (youth,

adolescent, young people, teen, preteen, pre-teen, young adult, paediatric, family), and (prevent, health promotion, wellness, promote). A search was also completed in each database to identify additional search terms. The authors used all chosen keywords and index terms to complete the database searches on 9 May 2022 for articles published since the date of each database's inception. Additional studies were identified through targeted searches of grey literature from USask iPortal, National Collaboration Centre for Indigenous Health, First Nations Child & Family Caring Society and Arctic Health. The authors also searched reference lists of selected sources for additional works.

Study selection

References identified during the searches were uploaded into DistillerSR [29] and duplicates were removed. Two authors (MB and SH) independently reviewed abstracts and titles of all retrieved articles and assessed them against the inclusion criteria (Table 1). Studies that met inclusion criteria were retrieved for full-text review. In cases of disagreement, consensus on whether to screen the full article text was discussed between the two authors, and a third author (SS) was consulted as needed. Next, the same two authors (MB and SH) independently screened full-text articles for inclusion and excluded those not meeting the inclusion criteria; reasons for exclusion are provided in the PRISMA flow diagram (Figure 1). Again, consensus was reached on inclusion or exclusion first through discussion and then consultation of an additional author (SS). Discussions were also held at several times throughout the review process to ensure alignment with the study purpose.

Assessment of methodological quality

Two authors (MB and SH) independently critically appraised the selected studies for methodological quality

using the appropriate JBI Critical Appraisal Tools JBI [30]. Seven articles were eligible for inclusion and one was excluded based on quality because it did not measure outcomes reliably for comparison [31]. There were no disagreements during this stage. If the critical appraisal tool criteria were clearly met, authors answered yes; if some criteria were clearly met but others were not addressed, authors answered unclear; and if criteria were clearly not met authors answered no (Tables 2 and 3).

Data extraction, synthesis and integration

Quantitative data were extracted by one author (SH) using the appropriate JBI data extraction tool [39] including details about the country, design, context, population, groups, outcomes and results. A second author (SS) confirmed the accuracy of data extraction. The authors intended to take a convergent, segregated approach to data synthesis and integration, with the aim to highlight diverse forms of knowledge; however, no qualitative studies remained following full-text review and thus only quantitative results were analysed. Due to heterogeneous study designs, meta-analysis was not possible. Petticrew and Roberts's [40] three stages of narrative analysis were used to describe data from the seven articles. First, data were organised into discrete categories including study characteristics (design, setting, intervention, population and measures) and outcomes (Tables 4 and 5). Second, a within-study analysis was completed, producing a narrative description of the results of each study. Last, cross-study synthesis generated an overall summary of the results, while taking account of variations in study design and quality (variations in populations, interventions and settings) [40]. Data synthesis and integration were discussed amongst the authors multiple times with respect to content, identification of key findings, strengths, limitations and implications for future research.

Table 1. Inclusion and exclusion criteria.

Inclusion Criteria	Exclusion Criteria
a) Interventions with Indigenous youth (age 13–19)	a) Interventions do not include Indigenous youth (age 13–19)
b) Inclusion of youth prior to type 2 diabetes diagnosis	b) Indigenous communities, culture or worldview not included at any point in intervention development
c) Intervention development includes Indigenous community member/s or Indigenous culture	c) Inclusion of youth with pre-existing diagnosis of type 2 diabetes and type 1 diabetes.
d) Preventative interventions that target prevention of type 2 diabetes diagnosis, or slowing onset	d) No measure of effectiveness of the intervention or description of youth experience
e) Include a measure of effectiveness of the intervention or description of youth experience	e) Published in any language other than English
f) Published in English	f) Opinion articles
g) Any country of origin	
h) Any intervention type	
i) Peer-reviewed original research studies, reviews	
j) Non-peer reviewed theses, programme or service reports	
k) Articles published between inception and May 2022	

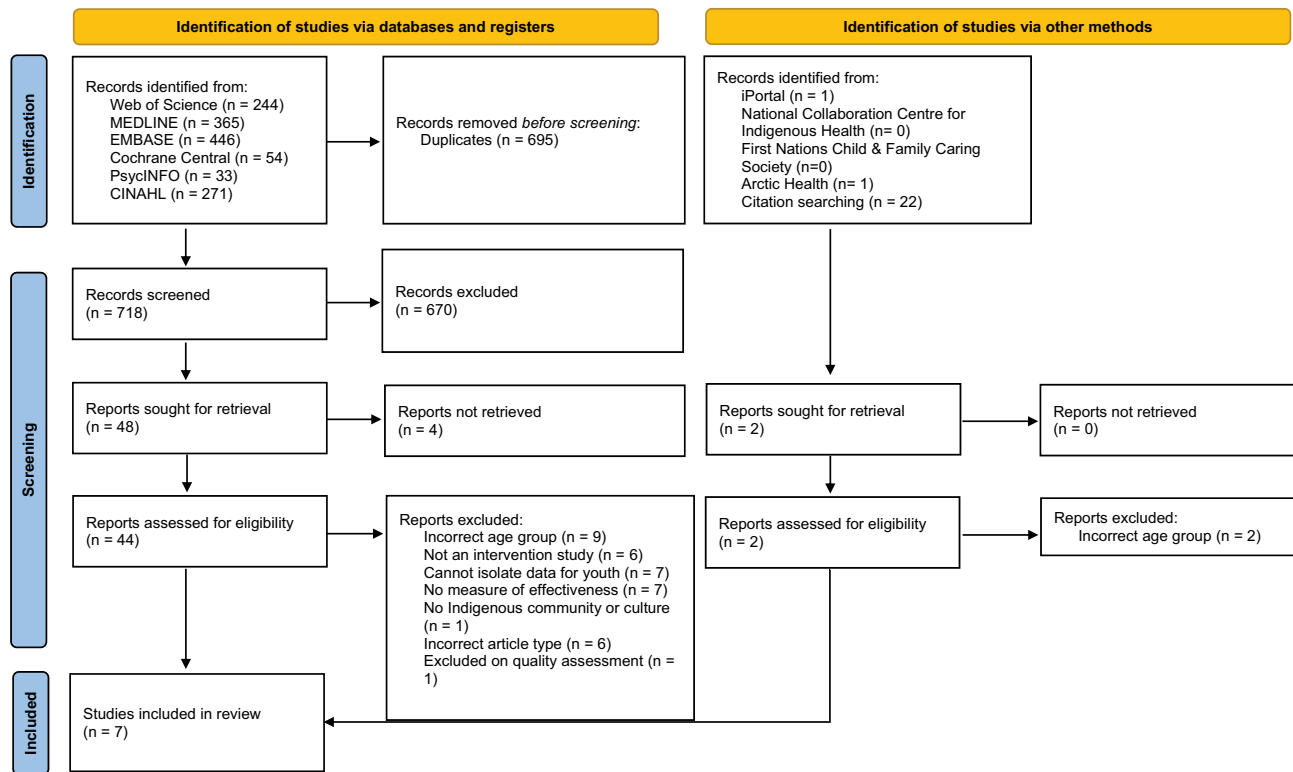


Figure 1. PRISMA flow diagram.

From: 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. *BMJ* 2021;372:n71. doi: 10.1136/bmj.n71. For more information, visit: <http://www.prisma-statement.org/>

Table 2. Critical appraisal of identified sources – quasi-experimental studies.

JBI Checklist Questions	Ducharme-Smith et al. 2021 [32]	Gachupin et al. 2019 [33]	Kenney et al. 2016 [34]	Marlow et al. 1998 [31]	Ritenbaugh et al. 2003 [35]	Ronsley et al. 2013 [36]	Teufel & Ritenbaugh 1998 [37]
1. Is it clear in the study what is the “cause” and what is the “effect” (i.e. there is no confusion about which variable comes first)?	Y	Y	Y	Y	Y	Y	Y
2. Were the participants included in any comparisons similar?	NA	NA	NA	NA	N	Y	N
3. Were the participants included in any comparisons receiving similar treatment/care, other than the exposure or intervention of interest?	NA	NA	NA	NA	U	Y	U
4. Was there a control group?	N	N	N	N	Y	Y	Y
5. Were there multiple measurements of the outcome both pre and post the intervention/exposure?	Y	Y	Y	Y	Y	Y	Y
6. Was follow-up complete and if not, were differences between groups in terms of their follow-up adequately described and analysed?	U	Y	U	N	N	Y	N
7. Were the outcomes of participants included in any comparisons measured in the same way?	Y	Y	Y	U	Y	Y	Y
8. Were outcomes measured in a reliable way?	Y	Y	Y	N	Y	Y	Y
9. Was appropriate statistical analysis used?	Y	Y	Y	N	Y	Y	Y

Terms: Y - Yes, N - No, U - Unknown

Results

A total of 718 articles were screened, with seven deemed eligible for inclusion in this systematic review based on the focus on community-based health promotion and prevention interventions with Indigenous youth without a T2D diagnosis, along with those with known risks for

prediabetes and T2D. The results describe seven articles reflective of five separate studies and highlight specific community-based interventions to promote wellness and prevent T2D among Indigenous youth. Additionally, the results identify specific ways in which interventions have been evaluated using a range of measures of effectiveness.

Table 3. Critical appraisal of identified sources – randomised controlled trial.

JBI Checklist Questions	Brown et al. 2013 [38]
1. Was true randomisation used for assignment of participants to treatment groups?	Y
2. Was allocation to treatment groups concealed?	N
3. Were treatment groups similar at baseline?	Y
4. Were participants blind to treatment assignment?	N
5. Were those delivering the treatment blind to treatment assignment?	N
6. Were outcomes assessors blind to treatment assignment?	N
7. Were treatment groups treated identically other than the intervention of interest?	Y
8. Was follow-up complete and, if not, were differences between groups in terms of their follow-up adequately described and analysed?	Y
9. Were participants analysed in the groups to which they were randomised?	Y
10. Were outcomes measured in the same way for treatment groups?	Y
11. Were outcomes measured in a reliable way?	Y
12. Was appropriate statistical analysis used?	Y

Terms: Y - yes, N - No

Study characteristics

The articles reported on studies that were conducted in North America including the United States of America (USA) [32–35,37,38] and Canada [36]. Four used a quasi-experimental design and one was a randomised control trial (RCT). The first quasi-experimental study, titled the *Together on Diabetes* (TOD) Program, was an adaption of an existing home-visiting diabetes prevention and management intervention for youth and adult support persons. The intervention included a 12-lesson education programme for Indigenous youth and was based on goal setting, nutrition and life skills [32,34]. The second study was an assessment of usual dietary intake in American-Indian youth who attended a 1-week wellness camp programme with five components that included cultural capital, structured education sessions, anthropometric and risk behaviour measurements, physical engagement and health messaging [33,41]. A third study (conducted with Zuni Pueblo youth in the USA) investigated the feasibility and efficacy of a high-school-based diabetes prevention intervention [35,37], which included strategies to: establish supportive social networks, construct a wellness facility, integrate diabetes education into the curriculum and modify the food supply available within the school. The fourth quasi-experimental study was conducted in remote coastal communities in Western Canada and evaluated *Healthy Buddies*, a curriculum-based, peer-led programme designed to promote healthy eating, physical activity and self-esteem [36]. In this study, the communities collaborated in the revision of the programme to ensure cultural and environmental appropriateness including modification of the lessons to include traditional foods and activities. The RCT assessed the effectiveness of a lifestyle change programme for Native American youth titled the *Diabetes*

Prevention Program (DPP) including healthy weight management, lowering fat intake and increasing physical activity [38].

The study designs included a formative phase to ensure active engagement of the communities in the research process. Four studies discussed the community-based participatory action (CBPAR) research design whereby collaborative partnerships were formed and regular meetings were held with community members and researchers regarding the design, implementation, evaluation and long-term sustainability of the programmes [32,34–38]. Although one article about the wellness camp for American-Indian youth did not specify a CBPAR approach, the authors described the tribal-university partnership and bi-monthly planning committee meetings [41].

There was considerable variance in the measures and outcomes that were reported across the seven articles. However, physical measures such as weight and height were consistently measured in all studies. Waist circumference (WC) was reported in six articles [32–34,36,37], blood pressure in three articles [32–34] and blood glucose (HbA1C, fasting blood glucose and oral glucose tolerance test) in five articles [32–35,37]. Additional blood measurements included plasma insulin [35,37] and cholesterol [33]. Similarly, nutrition intake was assessed in all studies, although different measures were used including the food frequency questionnaire (FFQ) [32,36], 24-h food recall [33,35,37] and an adapted knowledge, attitudes, and behaviour nutrition survey [38]. Physical activity was also investigated in all but one article, with adoption of different measures including a three-day physical activity recall questionnaire [32,35,37], heart rate monitoring including recovery and step tests [35,37], the physical activity questionnaire for adolescents and children (PAQ-A and PAQ-C) and the modifiable physical activity questionnaire for self-report for adolescents (MAQ-A) [38]. Other measurements

Table 4. Characteristics of included studies.

Study	Country	Setting/context	Participant characteristics	Intervention	Community involvement in Intervention Development	Outcomes measured
Ducharme-Smith et al. [32]	USA	Four reservation-based, rural tribal communities in southwestern United States: three Navajo communities and the White Mountain Apache Tribe Together on Diabetes (TOD) Program: Family-based (youth and an adult support person), home-visiting diabetes prevention and management intervention (Oct 2012 to June 2014). Included (1) Educational sessions for youth: 12, 45–60-min biweekly lessons during 6-month intervention phase followed by 20-min maintenance lessons every 6 months, (2) Educational sessions for support person: 4, 20–30-min lessons over 12 months, (3) Collaboration with medical providers, and (4) Referrals to community resources and wellness events.	217 American Indian youth (10–19 years) who lived within 50 miles of the community's Indian Health Service hospital with Type 2 Diabetes diagnosis, prediabetes or at risk	Intervention (one group): Mean age 13.6, 44.1% female, 13.7% overweight, 82.4% obese.	TOD programme developed through partnership with Johns Hopkins Center for American Indian Health and four reservation-based rural tribal communities in southwestern USA; Intervention was informed by advisory boards in each community and a cross-site steering committee with key personnel over 9-month formative phase	Baseline and post (3, 4 and 12 months after intervention) Baseline: Demographic Data Baseline and post: Psychosocial: Paediatric Quality of life, Patient Health Questionnaire Knowledge: 25 multiple choice developed by research team Food Intake: adapted Block Food Frequency Questionnaire Physical activity: 3-day physical activity recall questionnaire interview Physiologic: height, weight, Waste Circumference, Blood pressure, Hemoglobin A1c
Kenney et al. [34]	USA	See Ducharme-Smith et al. [32]	See Ducharme-Smith et al. [32]	See Ducharme-Smith et al. [32]	See Ducharme-Smith et al. [32]	See Ducharme-Smith et al. [32]
Gachupin et al. [33]	USA	Three different southwest tribes in Arizona AI Youth Wellness Camp: 1-week intensive residential camp programme (Described in more detail in previous paper)	26 American-Indian youth (10–15 years) Self-selected or referred by local tribal health programmes based on risk factors for T2D	Intervention (one group): Mean age 11.4, 65.4% female, 78% overweight or obese, 59% obese	Wellness camp includes tribal-university partnership; planning committee meets bi-monthly and includes University of Arizona camp director and tribal health personnel: paediatrician, physician assistant, registered nurse, registered dietitians, certified physical activity instructors, tribal wellness coordinators, Tribal Diabetes Program director, several tribal Community Health Representatives	Baseline and post (within 6 weeks before and after intervention) Baseline: Physiologic: height, weight, waist circumference, fasting cholesterol, fasting blood glucose, Hemoglobin A1c, blood pressure, heart rate Baseline and post: Food Intake: 24-h dietary recalls; each recall included 3 days (2 weekdays and 1 weekend day)

(Continued)

Table 4. (Continued).

Study	Country	Setting/context	Participant characteristics	Intervention	Community involvement in Intervention Development	Outcomes measured
Ritenbaugh et al. [35]	USA	Zuni Pueblo School-based intervention to change behaviours thought to affect diabetes risk: food intake, physical activity and knowledge r/t diabetes Established Zuni Teen Wellness Center (ZTWC) at Zuni High School, provided water coolers, replaced regular soft drinks with diet, altered contents of school lunches, education on diabetes through peer-created posters, announcements, learning units in classes specific to diabetes, elective on diabetes prevention	High school youth (n = 400) of Zuni High School (targeted 11th and 12th grade students; only 16–18 years for invasive measurements)	Intervention: Mean age 17.2–17.9; 48.8–55.5% female Control: 38 Anglo youth from a single high school in Tucson enrolled in two cohorts for cross-sectional data aged 17–19 with no Latino or Native American heritage	For 6 years the Pueblo of Zuni, Zuni Public School District, and University of Arizona collaborated in development, implementation and evaluation	Baseline, midproject (year 1.5), and post (year 3) Physiologic: height, weight, Waste Circumference, Body mass index, modified Oral Glucose Tolerance Test Food Intake: In-school soft drink vending machine sales, 24-h diet recall Physical activity: use of ZTWC, activity recalls, heart rate monitoring, step test and recovery heart rate Knowledge, attitude, beliefs: Questionnaire
Teufel and Ritenbaugh [37], Ronsley et al. [36]	USA	See Ritenbaugh et al. [35]	See Ritenbaugh et al. [35]	See Ritenbaugh et al. [35]	See Ritenbaugh et al. [35]	See Ritenbaugh et al. [35]
	Canada	3 First Nations Bands that are a part of Tsimshian Nation. Remote communities only accessible by boat or float plan in northern Pacific Coast of British Columbia. Healthy Buddies: Targets (1) physical activity, (2) healthy eating, (3) healthy body image Whole school model based on prescribed learning outcomes from British Columbia ministry of Education (21 lessons, six fitness loops – 30 min each); older and younger students become buddies and older teach younger	Grade 4–12 students (n = 179) completed evaluation questionnaires (Grade K–12 students participated in intervention)	Intervention: School A & B Control: School C	Collaborative relationships between three Indigenous communities and University of British Columbia; community members provided feedback on key needs for intervention and chosen intervention was modified to address communities' feedback	Baseline and post (9 months later) Physiologic: weight, height, Waste Circumference, Blood Pressure Knowledge and self-esteem: Healthy Buddies Questionnaire Food Intake: Food Frequency Questionnaire Physical Activity: Physical Activity Questionnaire(PAQ) – PAQ-Children/PAQ-Adults
Brown et al. [38]	USA	Two American Indian reservations in north-central and southwestern Montana Journey Diabetes Prevention Program (DPP): nine information and resource sessions over 3 months (every one-and-a-half weeks) targeting healthy weight maintenance, lowering fat intake, increasing physical activity.	Northern Plains American Indian youth (n = 93) (10–14 years)	Intervention: 4 Journey Diabetes Prevention Program (average eight youth per group). Mean age 11.4. Control: 4 comparison (average eight youth per group)	CBPR approach actively engaging Northern Plains Indian communities in all aspects of research process; collaborative research relationship for application for funding, study name, design, recruitment, evaluation and planning for long-term sustainability of Journey DPP	Baseline and post (3 months after baseline) Food Intake: 24-h dietary recall, adaptation of Knowledge, Attitudes, Beliefs nutrition questionnaire Physical activity: accelerometer for 7 days, Modifiable Physical Activity Questionnaire for Adolescents for self-report of Physical activity and sedentary time Physiologic: weight

Table 5. Outcomes of included studies.

Study	Physiologic	Food Intake	Physical Activity	Knowledge	Psychosocial
Ducharme-Smith et al. [32]		Significant caloric reduction; significant decrease in intake of fruit, whole grains, nuts and legumes; increase in trans-fat; significant decrease in sugar sweetened beverages, red/processed meat and sodium.			
Kenney et al. [34]	Decrease in Body Mass Index scores from baseline to 6 and 12 months ($p = 0.024$, 0.004); mean Waist circumference stayed consistent; percentage of youth w hypertension decreased at follow-ups ($p = 0.002$, 0.026)	Median calories from sweets and fats remained consistent; significant decreased servings of fruit and grains at follow-up.		Higher knowledge scores related to Together on Diabetes (TOD) content at 6 and 12 months	Significantly higher Quality of life (physical, psychosocial, emotional, school, social) at 6 months and 12 months with sustained improvements from 6 to 12 months; average scores changed from below average for healthy children to equivalent at 12 months; significant decrease in children who screened positive for depression at 6 months and 12 months
Gachupin et al. [33] Ritenbaugh et al. [35] Teufel and Ritenbaugh [37], Ronsley et al. [36]	Significant downward trend in fasting insulin values, 30-min insulin values Significant increase in fasting glucose levels for females; significant lower fasting and 30-min postprandial insulin levels for males Significant decrease in Body Mass Index, Waist circumference; mean Blood pressure increased more in control vs. Healthy Buddies (HB) group	Total fat significantly decreased. Decreased consumption of sugared soft drinks. Significant reduction in soft drink consumption. Milk, fruit and veg intake decreased slightly in Healthy Buddies and control.	Increased use of facility		
Brown et al. [38]	Small increases in Body Mass Index (BMI) with no differences between groups	Greater reduction in percentage of kcals from fat and saturated fat vs. comparison (but variability large); increased overall nutrition Knowledge, Attitudes and Beliefs (KAB) score.	Accelerometer measure was worse for both groups post; screen time decreased in intervention vs. increased in control	Improvement in nutrition food knowledge, food consumption	Self-esteem significantly increased for Healthy Buddies group vs. control

were assessed via surveys including a paediatric quality of life (PedsQL) questionnaire [32], a knowledge, attitude and beliefs questionnaire (KAB) [35,37], and a healthy buddies questionnaire which consisted of eight scales [36].

Participant characteristics

Although all studies identified participants as Indigenous youth or adolescents, they were of varied ages, with some being as young as 9 or 10 years, and as old as 19 years. There was also variance related to location, culture and language. Three articles reported the population to be American Indian youth from a Navajo (Apache) tribe [32,34], three different communities from southwest Arizona [33] and two Indigenous communities from Southwestern Montana [38]. Participants in two other studies were identified as Zuni Pueblo from New Mexico [35,37] and from the Tsimshian Nation in north coastal British Columbia, Canada [36]. Sample sizes varied from 26 to 400, and interventions ranged in length from a 1-week wellness camp to 4 years of school programming. One study included participants with T2D or pre-diabetes and youth without these diagnoses [32,34]. The study characteristics are summarised in Table 4.

Overview of the interventions and outcomes

Although there were variations in the study designs, measures and participants, each article contributed to understanding the community-based interventions that have been implemented to prevent diagnosis or delay the onset of T2D among Indigenous youth. With an aim to capture those deemed effective based on the evaluation reported in these articles, the significant results for youth without diagnoses of prediabetes or T2D were analysed and synthesised, as described in the following sub-sections. Outcomes from each article are also presented in Table 5.

Promoting physical wellness

All interventions focused on promoting physical wellness and were evaluated for their efficacy in this regard. In five articles, the authors reported measuring baseline and post-intervention plasma glucose (HbA1C, fasting blood glucose or oral glucose tolerance) and/or plasma insulin, and cholesterol [32–35,37]. Significant results were identified in two articles about one study where the aim of the intervention was to enhance knowledge of T2D, support increased activity and fruit and vegetable intake and reduce soft drink consumption [35,37]. In this study, assessment occurred at three points across the 4-year project. Midpoint and endpoint results showed a steady

decline for both male and female Zuni Pueblo youth in fasting and 30-min plasma insulin levels, suggesting a decrease in the incidence of hyperinsulinemia [37].

Body mass index (BMI) and WC measurements were reported in all studies except Brown et al.'s [38] research in which the researchers focused on body weight. Of those that included BMI, only two studies reported significant differences post-intervention. The first article described a significant decrease in BMI scores from baseline to 6-month ($p = 0.024$) and 12-month ($p = 0.004$) follow-up, while the mean WC remained consistent [34]. Ronsley et al. [36] reported a significant decrease in both BMI and WC after the intervention was implemented throughout one school year.

Blood pressure (BP) was also examined in four studies [32–34,36], with significant differences being found in BP measurements at post-intervention. Specifically, Kenney et al. [34] and Ducharme-Smith et al. [32] found that those youth with hypertension had decreased BP at the 6- and 12-month follow-up ($p = 0.002$ and 0.026), respectively. Similarly, Ronsley et al. [36] found that 22% of youth had elevated BP at baseline, which decreased to 19.2% at follow-up.

Improving physical activity and establishing healthy eating patterns

Improving physical activity and establishing healthy eating patterns were a priority of all interventions. Four studies involved measurement of physical activity levels using varied measures [34–36,38]. Brown et al. [38] reported a 59-min decrease in moderate-to-vigorous activity ($p < 0.001$) and 111-min increase in sedentary activity ($p = 0.01$) in the control group compared to a non-significant reduction in the intervention group. Similarly, food intake was reported in all seven articles. In terms of diet quality, one study reported a decrease in average energy intake ($p < 0.001$) [32], red/processed meat ($p < 0.008$) and sodium intake ($p < 0.01$) across time points, and another reported a decrease in fat consumption [33]. Also notable was the decreased consumption of sugar-sweetened beverages reported in three studies [32,35,37], while decreased fruits and grains from baseline to follow-up at both 6 and 12 months in one study [34].

Enhanced knowledge

Education on various topics was a priority in all interventions. Knowledge was measured in four studies using different instruments [34–36,38]. In the TOD study, researchers developed and piloted survey items about diabetes prevention and management and social

skills [34]. Results showed that participants of the TOD programme had improved knowledge of diabetes at 6 ($p < 0.001$) and 12 months ($p < 0.001$) compared to baseline [34]. The KAB surveys were used to assess knowledge of nutrition [38] and diabetes, healthy food choices and physical activity [35]. However, only one study reported KAB nutrition scores of 8% higher ($p = 0.008$) post-intervention compared to the control group where no change was observed [38].

Psychosocial wellness

Psychosocial wellness was only addressed in two interventions, despite being an important dimension of health. Activities to promote self-esteem and quality of life were included in two interventions [34,36]. One included social support delivered by a family health coach, which was associated with a significantly higher quality of life at 6 ($p < 0.001$) and 12 months ($p < 0.001$) post-intervention and was consistent across physical, psychosocial, emotional, school and social subscales [34]. In comparison to baseline, youth who presented with depression reported significantly decreased symptoms at 6 (17.3% vs. 6.8%, $p < 0.001$) and 12 months (17.3% vs. 9.2%, $p < 0.001$) [34]. In a second study, positive body image was promoted through education about healthy growth and development, media awareness and social skills facilitated through a buddy system. Results indicated that self-esteem increased significantly in the Healthy Buddies group, whereas the control group scores decreased ($p = 0.05$) [36], showing promise for holistic health benefits that extend beyond physical measures.

Discussion

The findings from seven articles reflecting five separate studies were identified and synthesised to determine the nature of community-based interventions designed to prevent or delay the onset of T2D among Indigenous youth and their families. This review revealed a paucity of studies, as those specific to Indigenous youth were from North America only; this was also the case in Vincze et al.'s [22] review of culturally adapted nutritional interventions for Indigenous populations. Elsewhere, initiatives have differed in their focus, with target populations including younger or older individuals (e.g. Australia) [42,43] or those already diagnosed with T2D or prediabetes (e.g. New Zealand) [44]. Strategies were undertaken in each of the studies to align with community priorities and practices, which led to unique designs, intervention activities and measures. Additionally, the existing studies were diverse in

participant characteristics (age, culture, language and location), duration and outcomes. However, there was a common focus of interventions related to promotion of physical wellness, physical activity, healthy eating and enhanced knowledge, as well as psychosocial wellness to a lesser extent. Findings revealed that some interventions were effective in promoting health and wellness based on the evaluation measures, offering insight into the value of engaging Indigenous youth in community-based interventions.

Promoting physical wellness

As promoting physical wellness was a focus in all studies, physiologic effects of intervention activities were measured, with results showing significant reductions in BP [32,34,36], BMI [34,36], WC [36] and fasting plasma insulin levels [37]. Notably, interventions associated with these outcomes were longer than 1 year in duration and incorporated education lessons and behavioural modifications related to physical activity [34,36], healthy eating [34,36] and body image [36], as well as referrals to community resources [34,36] and establishment of support networks for youth [34]. Although there have been promising intervention studies related to T2D or obesity prevention in school-aged children, such as the Pathways, Sandy Lake Health and Diabetes and Kahnawake Schools Diabetes Prevention Projects [20,45,46], these studies did not include youth aged 13–19 years or report changes in physical wellness. Thus, the findings of improved blood pressure, BMI and WC among youth participants of three studies included in this review [32,34,36] are the only positive outcomes found within the literature reviewed. Accordingly, these results provide support for multi-strategy community-based interventions that are implemented over longer periods of time, as this allows time for health practices and supportive relationships to become established. However, future longitudinal research coupled with in-depth formative research is needed to continue to develop community-driven wellness programmes that meet the needs of the specific community.

Improving physical activity and healthy eating patterns

All community-based interventions had education lessons and/or behavioural modifications related to improved eating and increasing physical activity. In one study, exercise circuits were used to promote simple physical activity aimed at increasing heart rate, which was associated with improved BMI and WC [36]. However, regardless of length, intensity and

variety of intervention, physical activity levels did not improve in the youth over the long term. When examining physical activity interventions conducted with other populations, positive effects have been documented. For example, a current review reported significant findings from intense lifestyle interventions designed to improve body composition in younger children who were overweight/obese and/or diagnosed with T2D through supervised structured endurance exercise offered at least four times a week [47].

Another study examined differences in cultural connectedness and physical activity, revealing that Indigenous adults who were classified as more physically active reported a greater sense of identity, spirituality, traditions, exploration, commitment, affirmation/belonging and overall cultural connectedness [48]. Cultural connectedness was identified as a protective factor of physical activity for Indigenous adults and was measured with the Culture Connectedness Scale, which includes subscales about spirituality, traditions, cultural identity and an overall cultural connectedness score [48]. Being that effective interventions have been used to promote physical activity in adults and youth who are obese or diagnosed with T2D, the lack of significant findings from the systematic review illustrates the importance of considering the association of cultural connectedness with physical activities, as some traditional activities might be overlooked. Similarly, given that physical activity has been shown to interconnect and balance four dimensions of holistic health (physical, psychological, social/emotional and spiritual/cultural) [49], future research should include thorough evaluation of interventions that reflect community-led strategies to address upstream cultural determinants of physical activity specific to Indigenous communities and promote holistic wellness in Indigenous youth. Additionally, community-driven interventions that are grounded in Indigenous culture, language and practices can foster cultural connectedness in conjunction with healthy behaviour.

Several studies reported better diet quality resulting from the interventions [32–37], suggesting that this is a fruitful area for future efforts. However, nutritional knowledge and behaviour interventions must account for barriers at the community level, in that food security, transportation and poverty can pose challenges to accessing healthy foods [47]. Recognition of traditionally or culturally preferred and cultivated foods should also be included in future research.

Enhanced knowledge

Education was a primary focus in all interventions, with two studies reporting enhanced knowledge outcomes

[34,38]. These results are similar to those reported in prior research on the effectiveness of interventions related to enhanced knowledge and healthy eating with younger children [46,50,51]. Promising strategies for education and activities included modifying the food supply such as reducing access to sugary beverages and increasing fruits and vegetables in school food services [35,37]. Specific nutrition education was based on increasing knowledge about: 1) reading food labels and nutritional content; 2) nutritional facts and portion sizes; 3) energy balance; 4) importance of water intake; 5) whole foods and whole grains; 6) meal planning; and 7) micro and macro nutrients [32,34,36]. While a focus on T2D and preventative behaviour can be valuable, the existing research was surprisingly lacking in terms of inclusion of traditional and cultural knowledge related to wellness. Given the importance of passing on place-based historical knowledge to many Indigenous cultures, intergenerational teaching and learning through storytelling and role modelling offer an important avenue for future exploration within T2D prevention research.

Psychosocial wellness

Although not prevalent across the interventions, two included strategies for promoting psychosocial dimensions of health with respect to self-esteem and body image through peer-led education related to healthy growth and development, media awareness and social and life skills [34,36]. Previous T2D prevention programmes targeting children have also incorporated strategies to promote self-efficacy [20,51]. However, there are limited reports documenting activities or measuring psychosocial health in previous studies designed to prevent or delay the onset of T2D in Indigenous youth. These notable findings confirm that educational activities intended to develop social and life skills and media awareness show promise in promoting holistic wellness in youth. Future efforts are needed to understand how behavioural and educational interventions contribute to psychosocial wellness, with particular emphasis on Indigenous perspectives and the interconnection of physical health with psychosocial, spiritual and cultural dimensions.

Study characteristics

Important considerations emerging from this systematic review also relate to research design. Although all studies were community-based, incorporated culturally appropriate education and/or behavioural activities and had some positive outcomes, two of the studies' designs had limitations including the home-visiting programme [32,34] and 1-week

wellness camp [33]. Specifically, home-visiting programmes have been evaluated previously [20] and found to be labour intensive, expensive and not sustainable. Although participation was associated with decreased fat intake, the 1-week camp was too short to have a lasting impact on physical measures [33]; however, participation in a wellness camp in combination with other strategies showed promise in the Sandy Lake Health and Diabetes project [20], suggesting that such camps might be beneficial within multi-strategy interventions. While Brown et al.'s [38] RCT was well designed and included culturally informed strategies, the 3-month time frame potentially limited the effectiveness of the interventions. In contrast, the Zuni DPP (school-based interventions) and peer-led *Healthy Buddies* (a whole-school model) programmes used a multi-strategy approach over a longer period (minimum 1 year), which led to improved health outcomes for the Indigenous youth [35–37]. Although these findings confirm previous reports of effective school-based interventions conducted with young school-aged Indigenous children [20,45,46,52], the results of this systematic review support the use of widespread school-based culturally informed activities in T2D prevention programmes for Indigenous youth. Additionally, while peer support and community involvement have been integrated within existing interventions, future community-based interventions should include community-led multigenerational activities to support intergenerational teachings.

Although the protocol for a mixed methods systematic review was used, there were no published reports of qualitative research about Indigenous youth's experiences with community-based interventions aimed at preventing diagnosis or delaying the onset of T2D. This result illustrates the urgent need for research that is driven by communities and conducted in ways that prioritise Indigenous epistemology and conceptions of wellness. Indigenous research methods such as conversation, storytelling, interviews, story boards, sharing circles and photo-voice should also be used to explore the experiences, meanings and perspectives that Indigenous youth attach to the effectiveness of T2D interventions [53,54]. Similarly, such approaches can facilitate co-creation of T2D prevention interventions for youth, and implementation and evaluation strategies that are deemed meaningful by communities. Within such research, greater attention to holistic wellness and cultural connectedness is essential, as these dimensions were not evaluated in existing research. Furthermore, there is a need to work collaboratively with Indigenous communities to develop community-driven measures for evaluating the success of health-

promoting interventions in ways that resonate and enhance the understanding of Western biomedical-driven physiologic, dietary and physical activity metrics.

Strengths and limitations

This systematic review has several strengths including being the first published MMSR that examined community-based interventions for promoting wellbeing before diagnosis of T2D among Indigenous youth. The JBI protocol for MMSR was followed and, therefore, rigorous methods were used to produce valid results. Although the selected studies were based in North America, a broad search was conducted to capture a global perspective; research from other contexts did not fit the inclusion criteria, most often with respect to the age group, focus on youth without T2D or prediabetes or community engagement in the research process. The systematic review process was guided by Indigenous Knowledge Keepers and people with T2D living experience, including the development of the research questions and search terms. The review process was rigorous with two authors screening the search results at each level, while three authors carefully conducted the assessment, analysis, and reporting of the research using the JBI critical appraisal forms and standardised data extraction tools. Additionally, a team-based approach was utilised that included discussion of various aspects of the review with the research team and Indigenous community members including co-author, HT.

This review has limitations to consider. Most study designs were quasi-experimental, which limited the possibility of identifying the interventions as the cause of changes in health measures. Also, different western measures were used across the articles, complicating the synthesis and interpretation of study outcomes as the included studies were community-based, adding potential variability to the findings. Although our inclusion criteria were strict, the aggregate data reported in three articles included participants with known risk factors and/or prior diagnosis of diabetes [32,34], while another included youth from grades 4 to 12. After an in-depth discussion among the five authors, consensus was reached to include these articles because the reports were important and met all other criteria, and the interventions showed potential. Additionally, only published studies where the intervention effectiveness was measured or evaluated quantitatively were included in the systematic review, potentially missing relevant research that did not assess explicit outcomes. Last, participant characteristics varied, with the interventions being implemented with Indigenous youth who had diverse languages,

cultures and practices, limiting the generalisability of the results. However, similar to other studies conducted with Indigenous peoples, all articles reiterated that the effectiveness of community-based T2D prevention interventions for Indigenous youth was dependent on respect for cultural dynamics and community capacity. Thus, emphasis was placed on consistent dialogue, care, respect and extensive planning [20,55].

Conclusion

Type 2 diabetes is increasingly affecting youth populations worldwide, with high rates among Indigenous youth especially. This is particularly concerning since paediatric T2D is associated with lifelong health challenges and severe outcomes. Despite recent developments in the aetiology, treatment and prevention of T2D in youth, there is a paucity of knowledge about effective T2D interventions for Indigenous youth with or without their families. This MMSR investigated the nature of community-based interventions promoting health and wellness before diagnosis of T2D among Indigenous youth. The findings highlighted the varied designs, activities and measures that have been used to date, as well as common strategies. The findings suggest the value of multi-strategy interventions that include culturally informed activities focused on promoting holistic wellness, and are based in schools and conducted over a minimum of 1 year. Despite a focus on varied forms of evaluation in the review, the existing literature included a greater focus on biomedical measures for evaluating health, such as those related to physical health, diet and physical activity, whereas knowledge-based, cultural and psychosocial indicators were less commonly adopted. As such, there is a need to expand the focus of evaluation to account for Indigenous-driven evaluation tools reflective of diverse ways of knowing.

These systematic review findings can be used by health care practitioners, Indigenous youth, parents and communities as a basis for the development and implementation of T2D prevention interventions that build upon the existing research and identified gaps. Future research should adopt mixed methods approaches that reflect cultural diversity and Indigenous community priorities and worldviews including culturally informed activities and research methods. Additionally, community-driven health promotion strategies that integrate intergenerational teaching and cultural connectedness can enhance the effectiveness of interventions for preventing diagnosis or delaying the onset of T2D in Indigenous youth.

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Author contributions

SS, JB, MB, SO, CB, AFC and HT contributed to the conceptualisation of the research project. The literature search was conducted by SH. Study selection, critical appraisal, data extraction and analysis were completed by SH, MB, and SS. SS, MB and JB wrote the original draft. All authors read and provided feedback prior to approving the final draft. All authors have read and agreed to the published version of the manuscript.

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Geolocation information

North America

ORCID

Shelley Spurr  <http://orcid.org/0000-0001-6009-0368>
 Meredith Burles  <http://orcid.org/0000-0002-5553-8022>
 Carol Bullin  <http://orcid.org/0000-0002-5669-4174>
 Amanda Froehlich Chow  <http://orcid.org/0000-0002-7576-0237>

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