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REVIEW

The Effectiveness of Indigenous Knowledge-Based Lifestyle Interventions in Preventing Obesity and Type 2 Diabetes Mellitus in Indigenous Children in Canada: A Systematic Review

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Background: Indigenous children in Canada have high rates of obesity and type 2 diabetes mellitus (T2DM). Culturally appropriate interventions, guided by an Indigenous knowledge-based view of health, are crucial to target these conditions. The objective of this systematic review was to assess the impact of indigenous Knowledge-based lifestyle interventions on the prevention of obesity and T2DM in Indigenous children in Canada.

Methods: Database searches were conducted from inception until February 22, 2022. The main outcomes were changes in Body Mass Index (BMI) z-score and the development of T2DM. The other outcomes included adiposity, metabolic, and lifestyle determinants of health. The GRADE approach was used to assess confidence in the evidence.

Results: Four non-randomized controlled trials (non-RCTs) and six uncontrolled studies were identified. Peer-led interventions led to a reduction in BMI z-score and waist circumference. GRADE assessment revealed very low quality of evidence due to a lack of randomization and small sample sizes. There were no diabetes-specific reported programs.

Conclusion: Limited evidence from non-randomized studies suggest that peer-led indigenous Knowledge-based lifestyle interventions improve BMI z-score and central adiposity. There is a need for community-owned and adequately powered randomized studies for interventions that aim to treat and prevent obesity and T2DM in Indigenous children in Canada.

Systematic Review Registration: PROSPERO CRD42017072781.

Keywords: child, ethnicity, obesity, diabetes, prevention

Introduction

In the general population, obesity and type 2 diabetes mellitus (T2DM) are significant contributors to the global noncommunicable disease burden.[1,2] Both diseases have made generational leaps and now impact children. In Canada, one-in-three children have an elevated body mass, and these high overweight and obesity rates are driving T2DM in Canada and globally.[3]

Indigenous communities in Canada are disproportionately impacted by obesity and T2DM.[1,2] The incidence of T2DM in Indigenous children is up to 12.45/100,000 persons/year–one of the highest in the world, and Indigenous children account for almost half of the newly diagnosed T2DM cases annually.[4]

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The high rates of adverse metabolic outcomes in Indigenous communities in Canada are part of the legacy of colonization-driven intergenerational trauma, social disadvantage, racism, poverty, food insecurity, and change in dietary choices and traditional physical activities.[5–12]

Pediatric T2DM is an aggressive disorder with associated conditions such as nephropathy, dyslipidemia, obstructive sleep apnea, polycystic ovaries syndrome, and fatty liver disease.[13–15] There is an urgent need for prevention and treatment strategies to manage obesity and T2DM to improve health outcomes in this population.[16,17]

Tackling obesity and diabetes will require interventions to be owned, developed, and controlled by the Indigenous communities to ensure relevance, sustainability, and a nuanced approach that honors the unique culture and the Indigenous Ways of Knowing.[11,18]

Indigenous knowledge-based view of health encompasses the holistic vision of physical, mental, emotional, and spiritual dimensions, and it is connected to the land and the culture of Indigenous peoples.[19] This vision of health needs to be at the core of culturally appropriate Indigenous-led interventions to maximize their success.[20]

The objective of this systematic review was to assess the impact of Indigenous Knowledge-based lifestyle interventions on the prevention of obesity and T2DM in Indigenous children in Canada.

Methods

This systematic review was registered with the International Prospective Register of Systematic Reviews (PROSPERO CRD42017072781) and is reported in compliance with the Preferred Reporting Items for Systematic Review and Meta-Analysis (PRISMA) statement (Table S1).[21] The protocol describing the methods for this review has been published.[22]

Main Outcomes

For obesity, the changes in Body Mass Index (BMI) z-score with the implementation of the intervention was utilized as the main outcome. We attempted to define prevention as either the inclusion of populations that live with overweight and demonstrating a stabilization or reduction of BMI z-score, or those with obesity who had a drop in the BMI z-score to the overweight or non-obesity levels. It also encompassed populations with no obesity with stabilization of the BMI z-score with the intervention.

The diagnosis of T2DM was based on standardized criteria for the second main outcome of this review.[23]

Other Outcomes

The other outcomes pursued included changes in total adiposity as measured by Dual Energy X-Ray Absorptiometry (DXA) scans or bioelectrical impedance. Central adiposity was measured using waist circumference (WC), waist-to-hip ratio (WHR), waist-to-height ratio (WHtR), and subcutaneous fat was measured using skinfold thickness if reported. Other aims included assessing changes in lifestyle factors, including nutrition and fitness and metabolic profiles including glucose and lipid homeostasis.

Eligibility Criteria

We planned to include primary research reports of randomized controlled trials (RCTs), quasi-experimental studies, and uncontrolled before-and-after study designs, when available. The targeted studies recruited Indigenous boys and girls of First Nations, Inuit, or Métis communities who were <18 years old. Studies were included regardless of the publication date, setting, or language. Studies were excluded if participants were diagnosed with T2DM as they have already developed one of the main study outcomes.

Search Strategy

We searched several databases from inception to February 22nd, 2022. We included the Medical Literature Analysis and Retrieval System Online (MEDLINE), the Cochrane Database of Systematic Reviews, the Cochrane Controlled Register of Trials, The Cumulative Index to Nursing and Allied Health Literature (CINAHL), Excerpta Medica Database (Embase), SportDiscus, Web of Science, American Psychological Association (APA) PsycINFO and iPortal (an

Indigenous studies portal research tool).[24] The search strategies were created in collaboration with a Senior Health Sciences Librarian (Appendix 1).

The grey literature search was conducted in the ProQuest Dissertations and Theses A&I and ClinicalTrials.gov. Reference lists of included articles were also searched during full-text screening to identify potentially eligible studies.

Study Selection and Data Abstraction

Two teams of two independent reviewers screened the titles, abstracts, and full-text articles against the eligibility criteria. The reviewers met at every stage to review disagreements, and a third reviewer was available to arbitrate persistent differences.

Risk of Bias and Quality Assessments

We planned to assess the risk of bias of RCTs by using the revised tool from the Cochrane Collaboration 2 (RoB 2.0).[25] Non-randomized studies were to be evaluated using the Non-Randomized Studies - of Interventions tool (ROBINS-I), and uncontrolled studies were to be assessed using the University of Alberta Evidence-based Practice Center (UAEPC) assessment tool.[26,27] To determine confidence in the overall evidence base, we used the Grading of Recommendations, Assessment, Development, and Evaluation (GRADE) approach.[28]

Statistical Analysis

We used the chi-square test of homogeneity and inconsistency index (I^2) to evaluate heterogeneity. The Cochrane Collaboration targets were used, with a p-value of <0.1 and I^2 of 75% indicative of heterogeneity cutoffs, respectively.[22]

We did not use funnel plot or Egger's test to evaluate small study effect as initially planned due to the lack of studies. Instead, we made estimates based on unpublished data from conference abstracts or registered trials.[29] A random effects meta-analysis was planned but not performed for BMI z-score and WC due to the absence of studies reporting on similar populations, study designs, methods, outcomes and study heterogeneity.

Results

Search results

Database searches retrieved 3760 records, and grey literature searches retrieved 31 records (Figure 1). Eleven additional documents were identified from reference lists. After screening articles and removing duplicates we identified ten eligible studies in this systematic review, including four cross-sectional studies with a control arm and six before-and-after cross-sectional studies.[30–39]

Study Characteristics and Results

Table 1 reports the characteristics of the included studies. Nine studies involved First Nations communities[30–32,34,36–39] and one study was reported from a Métis community.[33]

All studies focused on school or community obesity-based lifestyle interventions (intervention group n=1328, controls n=382). All studies employed a participatory action-based approach to actively engage the community. Participatory action research (PAR) is specifically undertaken by researchers and communities they work with to ensure that interventions are curated to the specific needs of the community.[33]

Seven studies implemented a combination of diet, physical activity, and psychological support components and focused on self-esteem, attitude, and healthy relationships.[30–33,35,38,39] Two studies implemented diet and physical activity-based interventions,[34,37] and one focused on physical activity alone.[36] The duration of the interventions ranged from 4 to 48 months in six studies. The remaining four studies reported annual data from ongoing programs.

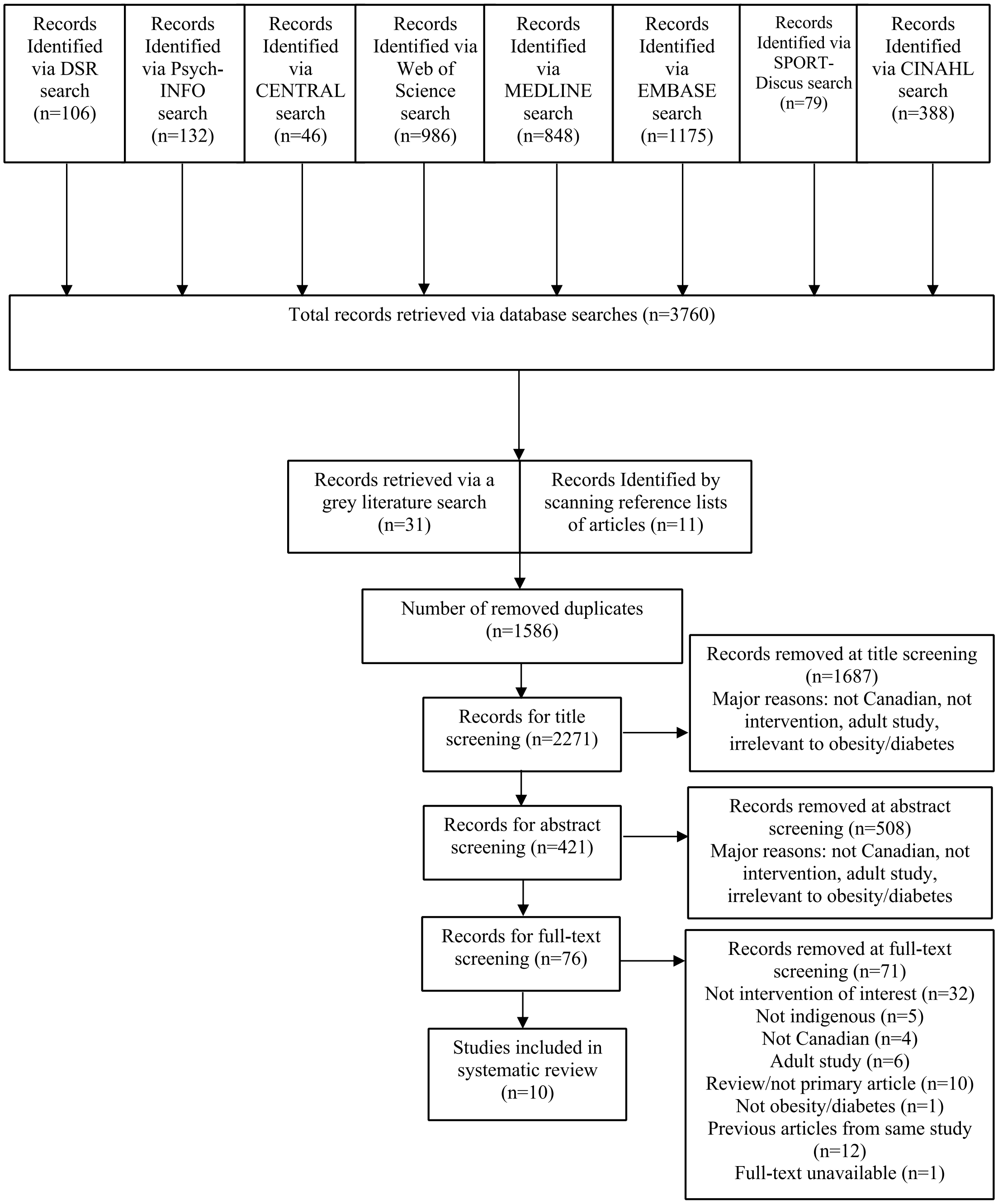

Figure 1 Article screening process flow chart.

Notable Programs and Results

Several unique models were reported in the studies. Notable school and community-based programs included the Sandy Lake Health and Diabetes Project (SLHDP) in Ontario, the Kahnawake School Diabetes Prevention Project (KSDPP) in Quebec, EarthBox Kids in Alberta and Healthy Buddies in British Columbia.[30,32,34,35,37,38]

The SLHDP is a non-randomized school-based diabetes prevention intervention that was established in 1991. The intervention incorporates Indigenous learning methods and aims to reduce the high prevalence of diabetes in the community via promoting physical activity and healthy nutrition.[34] The data were reported over two periods including 1998–1999 and 2005–2007.[34,37] Overall, both studies evaluating the SLHDP found an increase in mean BMI (kg/m^2) (Saksvig et al (2005) – pre: 20.5±4.3; post: 21.5±4.8; $p<0.001$; Kakekagumick et al (2013) – pre: 20.4; post: 23.1;

Table 1 Characteristics of Included Studies

Author (Year)	**Population**			**Lifestyle Interventions**		**Duration**	**Overall Results & Notes**
	Setting: Nation, Province	**Intervention Group**	**Control Group**	**Interventions**	**Outcomes**		
Repeated cross-sectional study of intervention with control arm (non-randomized)							
Paradis et al (2005)[32]	Kanien'keha´:ka Mohawk community (~200 miles southwest of Kahnawake) First Nation in Quebec One elementary school	N=458 (1994) N=446 (1996) Age: range 6–11 years Grades 1–6 F:M=N/A	N= 199 (1994) N= 195 (1996) Age: range 6–11 years F:M=N/A	Kahnawake Schools Diabetes Prevention Project (KSDPP) • School and community-based prevention program • Healthy eating and PA focus • Culturally relevant foods and activities incorporated • **School Program**: ten 45-minute lessons/year for each grade; curriculum includes education on T2DM, healthy nutrition, physical activity and fitness • **Community Program**: Use of local newspaper and radio advertisement and reporting results to community and promotional events • Incorporates participatory research and community ownership of the project	**Anthropometric Measures** • **BMI (kg/m^2)** Intervention; 1994: 17.24 (0.21); 1996: 19.04 (0.28) Control; 1994: 17.76 (0.41); 1996: 19.81 (0.54) • **Subscapular thickness (mm)** Intervention; 1994: 7.62 (0.35); 1996: 10.36 (0.49) Control; 1994: 9.05 (0.67); 1996: 14.88 (0.94) • **Triceps skinfold thickness (mm)** Intervention; 1994: 11.29 (0.33); 1996: 15.24 (0.45) Control; 1994: 10.84 (0.63); 1996: 17.43 (0.88) **Physical Activity** • **Physical activity frequency (# of 15-min episodes in last 7 days)** Intervention; 1994: 20.58 (1.08); 1996: 25.41 (1.49) Control; 1994: 17.64 (1.95); 1996: 22.14 (2.68) • **Run/Walk Frequency: best of 2 times for ½ or 1 mile (seconds)** Intervention; 1994: 452.32 (10.53); 1996: 550.96 (12.81) Control; 1994: 516.86 (20.37); 1996: 485.03 (24.78) **Nutrition** (scored from 0 (did not eat it) to 7 (every day)) • **Sugar consumption index** Intervention; 1994: 2.34 (0.15); 1996: 1.99 (0.12) Control; 1994: 2.18 (0.25); 1996: 1.72 (0.22) • **Fat consumption index** Intervention; 1994: 1.30 (0.08); 1996: 1.18 (0.09) Control; 1994: 1.16 (0.13); 1996: 1.17 (0.15) • **Fruit and vegetable consumption index** Intervention; 1994: 3.05 (0.16); 1996: 2.91 (0.15) Control; 1994: 3.28 (0.27); 1996: 3.57 (0.27)	• 8-year duration • 1994–2002 • Intervention group data collection: 1994–2002 (intervention group) • Control group data collection: 1994–1996 • A diabetes prevention program was started in the comparison community in 1996, which prevented additional data collection in this group. • Follow-up median: 2 years	Skinfold thickness increased less rapidly in intervention vs control group. Increase in BMI and no improvements in physical activity or dietary consumption

(*Continued*)

Table 1 (Continued).

Author (Year)	Population			Lifestyle Interventions		Duration	Overall Results & Notes
	Setting: Nation, Province	Intervention Group	Control Group	Interventions	Outcomes		
Ronsley et al (2013, non-randomized study of intervention, with control arm)[30]	Remote Tsimshian First Nation in British Columbia	(n = 118): • Age: 10.9±3.5 years • F:M=57:61	(n = 61): • Age: 10.6±3.4 years • F:M=30:31	Healthy Buddies^{TM} (HB) school-based program • 3 components: physical activity, healthy eating and healthy body image • Peer-led, "buddies" school program • 21 lessons and 6 fitness loops, each 30 minutes long • Two 30-min fitness session per week between "buddies" • Healthy eating targeted through lessons about nutritious and non-nutritious foods and beverages • Weekly 45-min information session with the senior students who then spent 30 min to teach the younger peer paired with them	**Anthropometry Measures** • **zBMI** Intervention; 2009: 1.10±0.99; 2010: 1.04±0.94; p=0.028 Control; 2009: 1.14±0.86; 2010: 1.23 ±0.78; p=0.046 • **Waist circumference (cm)** Intervention; 2009: 77.1±18.8 (2009); 2010: 75.0±17.1; p<0.0001* Control; 2009: 75.8±16.6; 2010: 75.5 ±15.3; p=0.961 **Physical Activity** • **PAQ (scored from 1 (low active) to 5 (very active))** Intervention; 2009: 3.05±0.94; 2010: 3.15±0.94 Control; 2009: 3.06±0.77; 2010: 3.14 ±1.03 **Nutrition** • **Sweetened sugar beverage consumption (SSB) (mL/week)** Intervention; 2009: 6497.4±6906.6; 2010: 5095.6±5097.9 Control; 2009: 5235.4±4666.1; 2010: 4764.1±6698.6 **Psychological measure** • **Self-esteem score** Intervention; 2009: 74.6±12.9; 2010: 77.3±12.2; p=0.005 Control; 2009: 76.7±14.9; 2010: 71.7±14; p=0.005	• 10-month duration • Program conducted during the 2009–2010 school year • Baseline measurements: September 2009 • Follow-up measurements: June 2010	Reduced BMI z-score and WC with intervention No changes, WC, PAQ, drink consumption 3 schools received HB training; however only schools A and B carried out the program; school C did not implement the program and was used as a control. Overall results suggested the intervention was ineffective at significantly improving secondary outcomes (WC, PA, drink and SSB consumption) when compared to control group.
Eskicioglu et al (2014, non-randomized study of intervention, with control arm) quasi-experimental trial with a parallel nonequivalent control arm[31]	Remote Oji-Cree First Nation in Manitoba (Kistiganwacheeng)	(n = 51): • Grade 4 students • Age: 9.7±0.4 years • F:M=38:13	(n = 100): • Grade 4+5 (36/64) students • Age: 10.4±0.7 years F:M=51:49	• Peer-led, after-school program • Culturally appropriate 90-minute program held once a week (approximately 5 months each year for 2 years) • The program was facilitated by volunteering high school students who were trained by the research assistants	**Anthropometry measures** • **zBMI** Intervention; 2010: 1.27 (1.17 to 1.37); 2010: 1.22 (1.11 to 1.32) Control; 2010: 1.26 (1.19 to 1.34); 2012: 1.30 (1.23 to 1.38) • **Waist circumference (cm)** Intervention; 2010: 77.8 (75.6 to 80.1); 2012: 78.2 (75.9 to 80.5); p<0.001 Control; 2010: 80.0 (78.4 to 81.6); 2012: 82.9 (81.2 to 84.5); p<0.001	• 10-month duration (two 5-month periods spread over 17 months) • Program offered from January-May in 2010–2011 and 2011–2012 school years	Reduced BMI z-score and WC 13 students crossed over to the control group in the second year

Oosman (2012, non-randomized study of intervention, with control arm)[33]	Île-à-la-Crosse, Saskatch-ewan	(n=16) ● Grades 3 and 4 ● Age: 8 and 9 years F:M=7:9	(n=22) ● Grades 3 and 4 ● Age: 8 and 9 years ● F:M=11:11	Métis culture-based comprehensive school health program ● School-based obesity and diabetes prevention ● Components: healthy eating, healthy eating education, PA	**Nutrition** ● **Food Frequency Questionnaire**: No statistically significant differences noted between intervention and control group overtime on consumption of sweets (eg cakes), savory foods (eg chips), candy/chocolates and soft drinks. **Physical Activity (PA)** ● **Moderate to vigorous physical activity (MVPA)** Significant decreases were noted in the standard care group from September to December. ● **KAB Questionnaire: leisure time and sedentary behaviour** (median score reported; 0=low level of sedentary behaviour, 12= high level of sedentary behaviour) No significant difference between intervention and control groups over time.	● 4-month duration ● September 2010 – December 2010	Mean intake of fruits and vegetables, milk and alternatives, low nutrient dense foods not significantly different in intervention vs control group over study period. Decrease in moderate-to-vigorous PA (MVPA) observed in the control group over study period, suggesting that the intervention had a protective effect.
Before-after repeated cross-sectional study							
Adams et al (2005)[35] Adams et al (2005, uncontrolled before-after)[35]	Kahnawake Mohawk First Nation in Quebec (15 km southwest of Montreal, Quebec, Canada) 2 elementary schools	n= 150 (1994) n= 145 (1998) ● Grades 4–6 ● Age: 8 to 12 years ● Age (mean): 9.9 years ● F:M=79:71 (1994) ● F:M=71:74 (1998)	N/A	Kahnawake Schools Diabetes Prevention Project (KSDPP) ● School and community-based prevention program ● Healthy eating and PA focus ● Culturally relevant foods and activities incorporated ● **School Program**: ten 45-minute lessons/year for each grade; curriculum includes education on T2DM, healthy nutrition, physical activity and fitness ● **Community Program**: Use of local newspaper and radio advertisement and reporting results to community and promotional events ● Incorporates participatory research and community ownership of the project.	**Anthropometry measures** ● **BMI (kg/m^2)** 1994: 20.30 (5.13); 1998: 20.27 (4.37); p=0.96 **Nutrition** ● **Higher quality diet** 1994: 52%; 1996: 55%; p=0.58 **Physical Activity** ● **Physical activity ≥30 min/day** 1994: 71%; 1996: 94%; p< 0.001	● 4-year duration ● 1994 to 1998	No reduction in BMI over the 4-year intervention period. Self-reported physical activity in Grade 4 to 6 children increased over 4 years of intervention.

(*Continued*)

Table 1 (Continued).

Author (Year)	Population			Lifestyle Interventions		Duration	Overall Results & Notes
	Setting: Nation, Province	Intervention Group	Control Group	Interventions	Outcomes		
Saksvig et al (2005, uncontrolled before-after)[34]	Remote First Nations community in Sandy Lake, Ontario	1998–1999 program: (n=122) • Grade 3, 4 and 5 students • Age: 7 to 14 years F:M= 55:67	N/A	School- and community based intervention (The Sandy Lake Health and Diabetes Project (SLHDP)) • Healthy eating (providing healthy snacks, school-wide ban on high-fat/ sugar foods and healthy recipe pamphlets) and PA (community walking trail, summer camps and events) focus • Aimed at preventing T2DM through obesity prevention • Components: Diabetes curriculum (3, 4 and 5th grade), family-engagement (eg weekly community radio show), peer-led (eg video cooking club), environmental and health eating school lunch program. • Incorporates ecological model, social cognitive therapy approaches and Indigenous learning styles (eg use of storytelling in lesson planning to make education culturally relevant • Third and fourth grade curriculum = 2 lessons/week for 17 weeks	**Anthropometry measures** • **BMI (kg/m^2)** 1998: 20.5±4.3; 1999: 21.5±4.8; p<0.001 • **Body fat (%)** 1998: 29.8%±10.7; 1999: 31.0±10.8; p<0.001 **Nutrition** • **Total fat (% energy)** 1998: 33.8±7.9; 1999: 31.9±8.3; p<0.05	• 1-year duration • 1998–1999 school year	Mean BMI and the % of body fat increased during the intervention period. The intervention was associated with meeting the + 5 g/d dietary fiber recommendation.
Tomlin et al (2012, uncontrolled before-after)[36]	Remote Northern First Nations communities in British Columbia	(n = 133): • Age: 12.4±2.2 years • F:M=63:70 • Baseline community characteristics: 20% overweight and 31% obesity	N/A	Action Schools! BC: A school-based physical activity and healthy eating intervention • Healthy eating (fruit and vegetable consumption) and PA focus (PA questionnaire and aerobic fitness test) • Whole-school model which consisted of classroom-based physical education (generally 75–80 minutes/week) and teachers incorporated daily physical activity (15min/day) physical activity and at least one health education activity per month.	**Anthropometry measures** • **zBMI** 2007: 1.12±0.86; 2008: 1.10±0.87; p=0.288 • **zWC** 2007: 0.46±1.07; 2008: 0.57±1.04; p=0.023 **Physical Activity** • PA Score (1=low activity; 5=high) activity) 2007: 2.75±0.72; 2008: 2.83±0.79; p=0.150 • MVPA (overall; min/day) **Nutrition** • # Vegetable type/day 2007: 1.10±1.18; 2008: 1.45±1.24; p=0.028	• 7-month duration • September 2007 – April/May 2008	Increased zWC Increased aerobic fitness No changes in BMI z-score, PA score, or dietary intake

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Kakekagumick et al (2013, uncontrolled before-after)[37]	Remote Oji-Cree First Nation of Sandy Lake in Northwest-ern Ontario	2005–2007 Program (n = 43): • Age: N/A • F:M=N/A	N/A	School- and community based intervention (The Sandy Lake Health and Diabetes Project (SLHDP)) • Healthy eating (providing healthy snacks, school-wide ban on high-fat/sugar foods and healthy recipe pamphlets) and PA (community walking trail, summer camps and events) focus • Aimed at preventing T2DM through obesity prevention • Components: Diabetes curriculum (3, 4 and 5th grade), family-engagement (eg weekly community radio show), peer-led (eg video cooking club), environmental and health eating school lunch program. • Incorporates ecological model, social cognitive therapy approaches and Native North American learning styles (eg use of storytelling in lesson planning to make education culturally relevant • Third and fourth grade curriculum = 2 lessons/week for 17 weeks	**Anthropometry measures** • **zBMI** 2005: 1.0; 2007: 1.3; p=0.001 • **BMI (kg/m^2), mean** 2005: 20.4; 2007: 23.1; p<0.001 • **Weight (kg)** 2005: 38.2; 2007: 49.2; p<0.001 • **WC (cm)** • 2005: 74.8; 2007: 84.1; p<0.001% **body fat** 2005: 32.0; 2007: 35.8; p<0.001 **Physical Activity** • **VO_2 Max (mL kg^{-1} min $^{-1}$)** 2005: 34.4; 2007: 31.0; p<0.001 **Nutrition** • Milk, mean (SE) 2005: 0.3 (0.1); 2007: 0.7 (0.1)** • Grains, mean (SE) 2005: 1.2 (0.2); 2007: 3.4 (0.8)**	• 16-month duration (two 8 month sessions over a 20 month period) • Baseline measurements in fall of 2005 • Follow-up measured in spring 2006, fall 2006 and spring 2007	Increased weight, BMI, BMI z-score, WC, % body fat Reduced VO_2 Max No changes in dietary intake
Triador et al (2015, uncontrolled before-after)[38]	Rural First Nations community in Alexander, Alberta	(n=76) • Grade 1–6 • Age: 9.0 ± 1.8 years • F:M=N/A	N/A	EarthBox Kids • Obesity prevention garden education project • Community-based participatory research initiative • 7-month classroom gardening activity with a 4-month weekly snack program	**Nutrition** • **Total vegetables and fruits preference (17-item questionnaire; 17=low preference; 102=high preference)** 2010: 81.0 (53–102); 2011: 83.5(47–102) p<0.017 • **Home consumption of vegetables and fruits** No change observed overtime.	• 11-month duration • November 2010-June 2011	Improvements in First Nations children's preferences for vegetables and fruit. Children's self-reported home consumption of foods did not improve. Limitation: small sample size and lack of control group.
Gates et al (2016, uncontrolled before-after)[39]	Remote Subarctic First Nations community in northern Ontario; Predominantly Cree background	(n=49) • Grade 6 to 8 • Age: 12.7±1.0 years • F:M= 20:29 (2013)	N/A	Healthy School Snack Program • School-based nutrition program to improve accessibility of healthy store-bought foods (with a focus on milk and milk products, vegetables and fruits) for youth. • Run by the school-based healthy snack program committee	**Nutrition** • **Vegetables and fruit mean daily intake ±SD** 2009: 2.3±2.0; 2013: 3.5±3.0; p=0.048* • **Milk and milk products mean daily intake ±SD** 2009: 2.2±1.9; 2013: 3.3±2.4; p=0.017* **Physical Activity** • **Change in MVPA from Oct 2012 to June 2013** Increased by 48 minutes per day; p = 0.016	• 4-year duration • May 2009 and June 2013 • After school sports program was implemented in October 2012	Improvements in the mean daily intake of vegetables and fruits, and milk and milk products. However, most children still did not meet intake recommendations for most food groups and nutrients. From October 2012-June 2013, an increase in time spent in moderate-to-vigorous physical activity was observed.

Notes: *statistically significant. **means are significantly different by post hoc multiple comparison using the least significant difference (LSD).

Abbreviations: BMI, body mass index (kg/m^2); F:M, female-to-male ratio; KAB, Knowledge, attitudes, beliefs questionnaire; MVPA, moderate-to-vigorous physical activity; N/A, not available; PA, physical activity; PAQ, physical activity questionnaire; WC, waist circumference; VO_2 max, maximum volume of oxygen (mL kg^{-1} min^{-1}); zWC, waist circumference z-score.

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p<0.001) and body fat percentage (Saksvig et al (2005) – pre: 29.8 ± 10.7%; post: 31.0 ± 10.8%, p-value< 0.001; Kakekagumick et al (2013) – pre: 32.0; post: 35.8%, p-value<0.001) with the intervention.[34,37] However, the program did report that students had improved knowledge about healthy foods and increased dietary self-efficacy.[34]

The KSDPP is a non-randomized long-term school- and community-based project in the Kahnawake community. This program prioritizes community involvement and ownership through promoting healthy habits among school-age children.[32,40] Two studies reported the results, with data reported over eight years for the intervention group, and two years for the control group in one study.[32,35] Only data over the two-year period for the intervention group where comparison data were available.[32] Overall, the first study evaluating the KSDPP reported an increase in BMI and no improvements in physical activity or dietary consumption.[32] Additionally, there was a less rapid increase in subscapular skinfold thickness (mm) in the intervention (pre: 7.62 ± 0.35 mm; post: 10.36 ± 0.49 mm) compared to the control group (9.05 ± 0.67 mm; 14.88 ± 0.94 mm) of children from a school in the Kanien'keha´:ka community located around 200 miles from the study community.[32] The second study reported no reduction in BMI over four years of intervention.[35] However, self-reported physical activity levels, defined as percentage of students who completed ≥30 mins of physical activity per day, increased over the intervention period (pre: 71%; post: 94%; p<0.001).[35]

The EarthBox Kids is a community-based participatory action research intervention in partnership with the University of Alberta, school staff, a community elder and an agriculture education specialist. This program was based on the social and cultural norms of the Alexander community in Alberta, and involved a 7-month classroom gardening activity and a 4-month weekly snack program.[38] At the end of the intervention, children reported fruit preferences that were similar to baseline, and had an improved vegetable preference score only for tomatoes. There were no data reported on body mass measures (Table 2 and Table 3).

The Healthy Buddies (HB) school-based, peer-led program comprises three key components including healthy eating, physical activity and self-esteem supports. One study reported an analysis of three Indigenous schools located in a remote Tsimshian First Nation community in British Columbia.[30] This program was also one of the only interventions that specifically contained the self-esteem component. The latter scores were reported to increase in the intervention group (pre: 74.6±12.9; post: 77.3±12.2) and decrease in the control group (pre: 76.7±14.9; post: 71.7±14) (interaction (time and group) p=0.005).[30]

Anthropometric Measures Changes with the Interventions

Two repeated cross-sectional studies including BMI z-score and WC were conducted in British Columbia and Manitoba and employed peer-led, school-based interventions.[30,31] The interventions were effective in improving the BMI z-score (Ronsley et al (2013) – pre: 1.10±0.99; post: 1.04±0.94; p=0.028; Eskicioglu et al (2014) – pre: 1.27 (1.17–1.37); post: 1.22 (1.11–1.32; p=0.007 between groups) and WC (Ronsley et al (2013) – pre: 77.1 ± 18.8 cm; post: 75.0 ± 17.1; Wilcoxon p<0.0001; Eskicioglu et al (2014) – pre: 77.8 (75.6 to 80.1); post: 78.2 (75.9 to 80.5); p<0.001 between groups) in the intervention group.[30,31] One uncontrolled study (n=133) found no change in BMI z-score (pre: 1.12±0.86; post: 1.10±0.87; p-value 0.288) and increased WC z-score with the intervention (pre: 0.46±1.07; post: 0.57±1.04, p<0.05).[36] Another uncontrolled study (n=35) reported an increase in BMI z-score (pre: 1.0; post: 1.3, p-value 0.001) and WC (pre: 74.8 cm; post: 84.1 cm, p-value <0.001) with the intervention (SLHDP) from baseline.[37]

Lifestyle Measures

Of the nine studies that reported on dietary changes with the intervention, two uncontrolled studies[34,39] reported a non-significant trend of dietary improvements.[30,32,33,35–38] One study reported improvements in daily intake of fruits and vegetables, however most participants did not meet the recommended intake for most food groups.[39] No studies reported changes in metabolic outcomes with interventions including glucose, insulin, Glycated Hemoglobin A1c (HbA1c), and lipid profile.

Risk of Bias and Overall Quality of Evidence

The UAEPC checklist was used to assess the risk of bias for six uncontrolled before-and-after studies (Table S2).[34–39] All studies had consecutive recruitment. Two studies were rated as having a low risk of bias due to standardized

Table 2 Effects of interventions on primary outcome; BMI z-score

Publication (Year)	Intervention Group		Control Group		Results
	Baseline:	**Follow-Up**	**Baseline:**	**Follow-Up**	
Tomlin et al (2012)[36]	Mean ± SD • BMI z-score: 1.12 ± 0.86	Mean ± SD • BMI z-score: 1.10 ± 0.87			**Intervention Group**: • p = 0.288 **Effectiveness**: • Overall, unclear results due to lack of control group • BMI z-score did not reduce to statistical significance within intervention group
Kakekagumick et al (2013)[37]	Mean • BMI z-score: 1.0	Mean Spring 2006 • BMI z-score: 1.1 Fall 2006 • BMI z-score: 1.2 Spring 2007 • BMI z-score: 1.3			**Over duration of the intervention**: • p = 0.001 **Effectiveness**: • Overall, ineffective • BMI z-score consistently increases over duration • Unclear whether increase is due to age changes; lack of control group to compare results
Ronsley et al (2013)[30]	Mean ± SD • BMI z-score: 1.10 ± 0.99	Mean ± SD • BMI z-score: 1.04 ± 0.94	Mean ± SD • BMI z-score: 1.14 ± 0.86	Mean ± SD • BMI z-score: 1.23 ± 0.78	**Intervention Group**: • p = 0.028 **Control Group**: • p = 0.046 **Between Groups** • p = 0.63 **Interaction (time and group)**: • p = 0.001 **Effectiveness**: • Overall, the intervention was effective at reducing BMI z-score within intervention group • Statistical significance was observed when compared to controls across time
Eskicioglu et al (2014)[31]	Mean (95% CI) • BMI z-score: 1.27 (1.17-1.37) • BMI z-score for overweight/ obese children only: 1.66 (1.60-1.77)	Mean (95% CI) • BMI z-score: 1.22 (1.11-1.32) • BMI z-score for overweight obese children only: 1.63 (1.52 - 1.74)	Mean (95% CI) • BMI z-score: 1.26 (1.19-1.34) • BMI z-score for overweight/ obese children only:1.73 (1.65-1.83)	Mean (95% CI) • BMI z-score: 1.30 (1.23-1.38) • BMI z-score for overweight/ obese children only: 1.74 (1.65–1.83)	**Group comparisons (all)**: • p = 0.007 **Group-wise Comparisons (overweight/obese children only)**: • p = 0.13 **Effectiveness**: • Results suggests effective at reducing BMI z-score compared to control

Abbreviations: BMI, body mass index (kg m^{-2}); CI, confidence interval; SD, standard deviation.

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Table 3 Effects of interventions on other outcomes

Publication (Year)	Skinfold Thickness, Weight Change, Waist Circumference, BMI, %BF, Physical Activity, Diet				Results
	Intervention Group		Control Group		
	Baseline:	Follow-Up	Baseline:	Follow-Up	
Repeated cross-sectional study of intervention with control arm (non-randomized)					
Paradis et al (2005)[32]	Baseline values measured in 1994 **Age and gender as covariates** Mean ± SD • BMI (kg/m2): 17.24 ± 0.21 • Skinfold thickness triceps (mm) †: 11.29 ± 0.33 • Skinfold thickness subscapular (mm) †: 7.62 ± 0.35 • Run/walk time*(s): 452.32 ±10.53 • No. 15 minute PA periods in 7 days: 20.58 ± 1.08 • Sugar consumption index**: 2.34 ± 0.15 • Fat consumption index**: 1.30 ± 0.08 • Fruit and vegetable consumption index**: 3.05 ± 0.16	Follow-up 1996: **Age and gender as covariates** Mean ±SD • BMI (kg/m2): 19.04 ± 0.28 • Skinfold thickness triceps (mm) †: 15.24 ± 0.45 • Skinfold thickness subscapular (mm) †: 10.36 ± 0.49 • Run/walk time*(s): 550.96 ±12.81 • No. 15-minute PA periods in 7 days: 25.41 ± 1.49 • Sugar consumption index**: 1.99 ± 0.12 • Fat consumption index**: 1.18 ± 0.09 • Fruit and vegetable consumption index**: 2.91 ± 0.15	Baseline values measured in 1994 **Age and gender as covariates** Mean ± SD • BMI (kg/m2): 17.76 ± 0.41 • Skinfold thickness triceps (mm) †: 10.84 ± 0.63 • Skinfold thickness subscapular (mm) †: 9.05 ± 0.67 • Run/walk time*(s): 516.86 ±20.37 • No. 15 minute PA periods in 7 days: 17.64 ± 1.95 • Sugar consumption index**: 2.18 ± 0.25 • Fat consumption index**: 1.16 ± 0.13 • Fruit and vegetable consumption index**: 3.28 ± 0.27	Follow up 1996: **Age and gender as covariates** Mean ±SD • BMI (kg/m2): 19.81 ± 0.54 • Skinfold thickness triceps (mm) †: 17.43 ± 0.88 • Skinfold thickness subscapular (mm) †: 14.88 ± 0.94 • Run/walk time*(s): 485.03± 24.78 • No. 15-minute PA periods in 7 days: 22.14 ± 2.68 • Sugar consumption index**: 1.72 ± 0.22 • Fat consumption index**: 1.17 ± 0.15 • Fruit and vegetable consumption index**: 3.57 ± 0.27	**Over comparison period of 1994-1996**: • Subscapular and triceps skinfold thickness: p < 0.01 • Run/walk time: p < 0.01 • Other outcomes: not significant **Effectiveness**: • Overall, results suggest the intervention was ineffective • BMI: similar increases in groups • Subscapular and tricep skinfold thickness: reduced to statistical significance • Run/walk time: control group improved, intervention group worsened • No. 15 minute PA periods in 7 days: similar increases in both groups • Nutrition indices: no significant changes between intervention and control groups. • Sugar, fat, fruit and vegetables consumption consistently decreased over 1994-2002 • Long-term results for intervention group: BMI continuously increased (adjusted for age and gender); skinfold thickness and PA level were inconsistent
Ronsley et al (2013)[30]	Mean ± SD • WC (cm): 77.1 ± 18.8 • PAQ Score: 3.05 ± 0.94 • Regular soda pop intake (mL/week): 1526.5 ± 2044.9 • SSB consumption (mL/week): 6497.4 ± 6906.6 • Self-esteem score: 74.6±12.9	Mean ± SD • WC (cm): 75.0 ± 17.1 • PAQ Score: 3.15 ± 0.94 • Regular soda pop intake (mL/week): 1176.1 ± 1565.1 • SSB consumption (mL/week): 5095.6 ± 5097.9 • Self-esteem score: 77.3±12.2	Mean ± SD • WC (cm): 75.8 ± 16.6 • PAQ Score: 3.06 ± 0.77 • Regular soda pop intake (mL/week): 1178.3 ± 1855.7 • SSB consumption (mL/week): 5235.4 ± 4666.1 • Self-esteem score: 76.7±14.9	Mean ± SD • WC (cm): 75.5 ± 15.3 • PAQ Score: 3.14 ± 1.03 • Regular soda pop intake (mL/week): 1557.8 ± 2752.9 • SSB consumption (mL/week): 4764.1 ± 6698.6 • Self-esteem score: 71.7±14	**Intervention Group**: • WC: Wilcoxon p < 0.0001 **Control Group**: • WC: Wilcoxon p = 0.961 **Between Groups**: • WC: p = 0.941 • PAQ score: p = 0.446 • Regular soda pop intake: p = 0.932 • SSB consumption: p = 0.424 **Interaction (time and group)**: • WC: p = 0.154 • PAQ: p = 0.393 • Regular soda pop intake: p = 0.149 • SSB consumption: p = 0.528 • Self-esteem score: p = 0.005 **Effectiveness**: Overall, results suggest the intervention was ineffective at significantly improving these secondary outcomes in comparison to control group
Eskicioglu et al (2014)[31]	Mean (95% CI) • WC (cm): 77.8 (75.6-80.1) • WC (cm) for overweight/obese children only: 82.0 (range 78.4-85.6)	Mean (95% CI) • WC (cm): 78.2 (75.9-80.5) • WC (cm) for overweight/obese children only: 82.4 (78.8 to 86.0)	Mean (95% CI) • WC (cm): 80.0 (78.4-81.6) • WC (cm) for overweight/ obese children only: 85.2 (82.1-88.2)	Mean (95% CI) • WC (cm): 82.9 (81.2 to 84.5) • WC (cm) for overweight/obese children only: 87.8 (84.8 to 90.7)	**Group comparisons (all)**: • WC: p < 0.001 **Group-wise Comparisons (overweight/obese children only)**: • WC: p = 0.02 **Effectiveness**: • WC: suggests effective at attenuating age-related increases in WC

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Oosman (2012)[33]	Median (range) • KAB score for leisure time sedentary activities: 6.0 (0–10) Average minutes per day (SD) • Sedentary activities: 484 (74) • Light activities: 210 (45) • Moderate activities: 65 (30) • Vigorous activities: 7 (5) • Moderate-to-vigorous activities: 72 (34)	Median (range) • KAB score for leisure time sedentary activities: 5.5 (1–10) Average minutes per day (SD) • Sedentary activities: 495 (43) • Light activities: 203 (42) • Moderate activities: 51 (20) • Vigorous activities: 5 (3) • Moderate-to-vigorous activities: 56 (23)	Median (range) • KAB score for leisure time sedentary activities: 5.0 (1–12) Average minutes per day (SD) • Sedentary activities: 463 (79) • Light activities: 222 (46) • Moderate activities: 68 (22) • Vigorous activities: 5 (3) Moderate-to-vigorous activities: 73 (24)	Median (range) • KAB score for leisure time sedentary activities: 5.0 (3–12) Average minutes per day (SD) • Sedentary activities: 527 (55) • Light activities: 196 (32) • Moderate activities: 47 (16) • Vigorous activities: 3 (2) Moderate-to-vigorous activities: 50 (18)	**FFQ scores in intervention group**: • Consumption of cakes, cookies, pie, doughnuts (Improve, No change, Worse): 46.2%, 30.8%, 23.1% • FFQ: Consumption of potato chips, nacho chips, cheezies, pretzels (Improve, No change, Worse): 35.6%, 50.0%, 14.3% • FFQ: Consumption of candy and chocolate bars (Improve, No change, Worse): 42.9%, 35.7%, 14.2% • FFQ: Consumption of regular soft drinks (Improve, No change, Worse): 50.0%, 35.7%, 14.2% **FFQ scores in control group**: • Consumption of cakes, cookies, pie, doughnuts (Improve, No change, Worse): 27.8%, 44.5%, 27.8% • FFQ: Consumption of potato chips, nacho chips, cheezies, pretzels (Improve, No change, Worse): 20.3%, 72.3%, 5.6% • FFQ: Consumption of candy and chocolate bars (Improve, No change, Worse): 42.2%, 36.9%, 21.1% FFQ: Consumption of regular soft drinks (Improve, No change, Worse): 31.0%, 47.3%, 21.1%
Before-after repeated cross-sectional study					
Adams et al (2005)[35]	Baseline values measured in 1994 • BMI, kg/m^2 (SD): 1994: 20.30 (5.13) • Higher-quality diet: 52% • PA ≥30 min/day: 71% 48% of children met recommendations of >5 servings of fruit/vegetables per day	Baseline values measured in 1998 • BMI, kg/m^2 (SD): 20.27 (4.37) • Higher quality diet: 55% • PA ≥30 min/day: 94% 41% of children met recommendations of >5 servings of fruit/vegetables per day			**Intervention group** Higher quality diet (p-value): 0.58
Saksvig et al (2005)[34]	Baseline values measured in 1998 • %BF: 29.8 ± 10.7 • Energy intake (kJ/d): 9552 ± 4763 • Total fat (g/d): 86.4 ± 51.4 • Total fat (% energy): 33.8 ± 7.9 • Carbohydrates (g/d): 308 ± 155 • Carbohydrates (% energy): 54.5 ± 10.0 • Total protein (g/d): 71.7 ± 44.4 • Protein (% energy): 12.5 ± 4.0 Total fiber (g/d): 11.6 ± 8.0	Baseline values measured in 1999 • %BF: 31.0 ± 10.8 • Energy intake (kJ/d): 9580 ± 3996 • Total fat (g/d): 83.3 ± 45.1 • Total fat (% energy): 31.9 ± 8.3 • Carbohydrates (g/d): 314 ± 137 • Carbohydrates (% energy): 55.4 ± 10.5 • Total protein (g/d): 77.1 ± 33.9 • Protein (% energy): 13.8 ± 4.6 Total fiber (g/d): 13.4 ± 8.0			**Intervention Group**: • %BF: p < 0.001 • Energy intake difference (kJ/d): 27.7 ± 6102 • Total fat difference (g/d): −3.0 ± 65.6 • Total fat difference (% energy): −2.0 ± 11.6 • Carbohydrates difference (g/d): 5.1 ± 204 • Carbohydrates difference (% energy): 0.91 ± 15.0 • Total protein difference (g/d): 5.4 ± 57.1 • Protein difference (% energy): 1.3 ± 6.1 • Total fiber difference (g/d): 1.8 ± 11.1
Tomlin et al (2012)[36]	Mean ± SD • zWC: 0.46 ± 1.07 • No. aerobic fitness laps: 25.4 ± 15.8 • PA score: 2.75 ± 0.72 • Kcal/day: 1839.8 ± 761.5 • % calories from sugar: 27.3 ± 13.3 • % calories from fat: 28.2 ± 9.0 SSB (mL/day): 835.4 ± 725.5	Mean ± SD • zWC: 0.57 ± 1.04 • No. aerobic fitness laps: 30.9 ± 20.0 • PA score: 2.83 ± 0.79 • Kcal/day: 1730.2 ± 744.2 • % calories from sugar: 28.4 ± 11.8 • % calories from fat: 27.2 ± 9.1 SSB (mL/day): 927.2 ± 553.4			**Intervention Group**: • zWC: p = 0.023 • No. aerobic fitness laps: p < 0.001 • PA Score: p = 0.150 • Kcal/day: p = 0.159 • % calories from sugar: p = 0.461 • % calories from fat: p = 0.354 • SSB: p = 0.158 **Effectiveness**: • Overall, unclear results due to lack of control group • zWC: increased No. aerobic fitness laps: effective, increased

(Continued)

Table 3 (Continued).

Publication (Year)	**Skinfold Thickness, Weight Change, Waist Circumference, BMI, %BF, Physical Activity, Diet**				**Results**
	Intervention Group		**Control Group**		
	Baseline:	**Follow-Up**	**Baseline:**	**Follow-Up**	
Kakekagumick et al (2013)[37]	2005-2007 Program Mean • BMI (kg/m2): 20.4 • WC (cm): 74.8 • %BF: 32.0 • Weight (kg): 38.2 • PA level (VO_2 Max): 34.4 1998-1999 Program Mean ± SD • Dietary fiber intake: 11.6 ± 8.0 • Dietary fat intake: 86.4 ± 51.4	2005-2007 Program Mean Spring 2006 • BMI (kg/m2): 21.2 • WC (cm): 76.9 • %BF: 33.2 • Weight (kg): 41.6 • PA level (VO_2 Max): 32.2 Fall 2006 • BMI (kg/m2): 21.7 • WC (cm): 76.8 • %BF: 33.9 • Weight (kg): 44.1 • PA level (VO_2 Max): 32.6 Spring 2007 • BMI (kg/m2): 23.1 • WC (cm): 84.1 • %BF: 35.8 • Weight (kg): 49.2 • PA level (VO_2 Max): 31.0 1998-1999 Program Mean ± SD • Dietary fiber intake: 13.4 ± 8.0 • Dietary fat intake: 83.3 ± 45.1			**Over duration of the intervention**: • BMI: $p < 0.001$ • WC: $p < 0.001$ • %BF: $p < 0.001$ • Weight (kg): $p < 0.001$ • PA level (VO_2 Max): $p < 0.001$ • Dietary intake: not significant **Effectiveness**: • Overall, ineffective • Anthropometric data (BMI, WC, %BF, weight) consistently increases over duration • Physical activity decreases for most of the duration (exception Fall 2006) • No significant change in dietary intake Unclear whether these decreases and increases are due to age changes due to lack of control group to compare to
Triador et al (2015)[38]	Median (range): • Grapes: 6 (4–6) • Orange: 6 (3–6) • Apple: 6 (3–6) • Pear: 6 (2–6) • Banana: 6 (1–6) • Carrot: 6 (1–6) • Kiwi: 6 (1–6) • Celery: 6 (1–6) • Cucumber: 6 (1–6) • Cantaloupe: 6 (1–6) • Broccoli: 5 (1–6) • Cauliflower: 5 (1–6) • Green pepper: 4 (1–6) • Tomato: 3 (1–6) • Radish: 3 (1–6) • Mushroom: 2 (1–6) • Grapefruit: 2 (1–6) • Total vegetables: 39.5 (14–54) • Total fruits: 42.0 (28–48) • Total vegetables and fruits: 81.0 (53–102)	Median (range): • Grapes: 6 (2–6) • Orange: 6 (2–6) • Apple: 6 (2–6) • Pear: 6 (1–6) • Banana: 6 (2–6) • Carrot: 6 (3–6) • Kiwi: 6 (2–6) • Celery: 6 (1–6) • Cucumber: 6 (1–6) • Cantaloupe: 6 (1–6) • Broccoli: 5.5 (1–6) • Cauliflower: 5.5 (1–6) • Green pepper: 5 (1–6) • Tomato: 4 (1–6) • Radish: 3 (1–6) • Mushroom: 3 (1–6) • Grapefruit: 2.5 (1–6) • Total vegetables: 42.0 (13–54) • Total fruits: 43.0 (14–48) • Total vegetables and fruits: 83.5 (47–102)			**Intervention group (z-score, p-value)** • Grapes: 0.90, 0.37 • Orange: 1.33, 0.18 • Apple: 0.14, 0.89 • Pear: 0.05, 0.96 • Banana: 1.07, 0.28 • Carrot: 0.82, 0.41 • Kiwi: 1.88, 0.06 • Celery: 0.28, 0.78 • Cucumber: 1.94, 0.05 • Cantaloupe: 2.06, 0.05 • Broccoli: 1.79, 0.07 • Cauliflower: 2.62, 0.01 • Green pepper: 1.86, 0.04 • Tomato: 3.30, 0.003 • Radish: 0.95, 0.34 • Mushroom: 1.96, 0.04 • Grapefruit: 1.27, 0.20 • Total vegetables: 3.05, 0.017 • Total fruits: 2.60, 0.017 • Total vegetables and fruits: 3.12, 0.017

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Gates et al (2016)[39]	Baseline values measured in May 2009 • Vegetables and fruits (servings/day): 2.3 ±2.0 • Milk and milk products (servings/day): 2.2 ±1.9 • Meat and alternatives (servings/day): 1.9 ±1.7 • Grain products (servings/day): 6.9±4.3 • "Other" foods (servings/day): 5.5±3.2 • Energy (kcal): 2079.6±1031.5 • Carbohydrates (g): 258.2±111.5 • Carbohydrate (% kcal): 52.9±13.6 • Protein (g): 74.5±47.0 • Protein (% kcal): 13.6±4.3 • Fat (g):84.5±54.2 • Fat (% kcal): 34.0±9.8 • Saturated fat (g): 32.0±22.2 • Saturated fat (% kcal): 12.9±4.5 • Fiber (g): 11.0±6.4 • Vitamin A (μg RAE): 319.6±275.7 • Vitamin D (μg): 2.4±2.4 • Thiamine (mg): 1.5±0.8 • Riboflavin (mg): 1.7±1.1 • Niacin (mg): 15.8±11.4 • Vitamin B6 (mg): 1.1±0.7 • Vitamin B12 (μg): 4.1±3.4 • Folate (μg DFE): 259.6±156.3 • Vitamin C (mg): 75.3±80.6 • Calcium (mg): 812.9±577.5 • Iron (mg): 15.1±8.0 • Potassium (mg): 1888.7±1111.5 • Sodium (mg): 3501.2±2234.7 • Zinc (mg): 9.3±6.8	Follow-up values measured in June 2013 • Vegetables and fruits (servings/day): 3.5 ±3.0 • Milk and milk products (servings/day): 3.3 ±2.4 • Meat and alternatives (servings/day): 2.0 ±1.7 • Grain products (servings/day): 8.0±4.3 • "Other" foods (servings/day): 7.7±4.6 • Energy (kcal): 2619.9±1165.6 • Carbohydrates (g): 335.0±148.0 • Carbohydrate (% kcal): 51.7±9.9 • Protein (g): 88.3±39.4 • Protein (% kcal): 14.0±4.3 • Fat (g): 105.5±60.3 • Fat (% kcal): 35.2±8.6 • Saturated fat (g): 38.3±21.9 • Saturated fat (% kcal): 12.9±4.1 • Fiber (g): 14.2±7.0 • Vitamin A (μg RAE): 413.7±304.3 • Vitamin D (μg): 3.1±2.9 • Thiamine (mg): 1.8±0.9 • Riboflavin (mg): 2.3±1.2 • Niacin (mg): 18.4±8.5 • Vitamin B6 (mg): 1.3±0.6 • Vitamin B12 (μg): 5.2±3.3 • Folate (μg DFE): 369.2±211.1 • Vitamin C (mg): 126.2±139.5 • Calcium (mg): 1145.0±693.9 • Iron (mg): 18.4±7.4 • Potassium (mg): 2568.4±1933.7 • Sodium (mg): 3863.2±1228.8 • Zinc (mg): 11.9±5.2			**Intervention group**: Change from 2009 to 2013 (p-value) • Vegetables and fruits: 0.048 • Milk and milk products: 0.017 • Meat and alternatives: 0.835 • Grain products: 0.230 • "Other" foods: 0.030 • Energy (kcal): 0.021 • Carbohydrates (g): 0.025 • Carbohydrate (% kcal): 0.615 • Protein (g): 0.126 • Protein (% kcal): 0.681 • Fat (g): 0.083 • Fat (% kcal): 0.530 • Saturated fat (g): 0.169 • Saturated fat (% kcal): 0.934 • Fiber (g): 0.019 • Vitamin A (μg RAE): 0.124 • Vitamin D (μg): 0.198 • Thiamine (mg): 0.040 • Riboflavin (mg): 0.008 • Niacin (mg): 0.209 • Vitamin B6 (mg): 0.126 • Vitamin B12 (μg): 0.116 • Folate (μg DFE): 0.006 • Vitamin C (mg): 0.249 • Calcium (mg): 0.015 • Iron (mg): 0.046 • Potassium (mg): 0.007 • Sodium (mg): 0.404 • Zinc (mg): 0.042 Change from October 2012 and June 2013 • Time spent in moderate-to-vigorous activity by 48 minutes per day (p=0.016)

Notes: ┼Mean of three. *Best of two times. **Scored on a scale of 0 (did not eat it) to 7 (every day).

Abbreviations: BMI, body mass index; FFQ: food frequency questionnaire; KAB: knowledge, attitudes, and beliefs; PA, physical activity; PAQ, physical activity questionnaire; WC, waist circumference; SD, standard deviation; SSB, sugar-sweetened beverages; %BF, percent body fat; VO_2 Max, maximum volume of oxygen uptake (ml kg^{-1} min^{-1}); zWC, waist circumference z-score.

measurement methods and appropriately addressing missing data.[35,36] The remaining four studies were rated at an overall unclear risk of bias due to the absence of independent outcome assessors.[34,37–39] Furthermore, the outcome assessors across all studies were not blinded, which may potentially contribute to reporting bias for dietary recall and physical activity.

For the four non-randomized controlled trials,[30–33] the ROBINS-I tool was used (Table S3). All four studies had a low risk of bias in the selection of participants and data reporting. The bias due to confounding and deviations was rated as moderate due to the potential for deviation from the intended interventions. Two studies[32,33] had a low risk of bias in the classification of intervention, but the other two[30,31] were rated as moderate due to logistical challenges. One study, for example, was originally designed to be a pre-/post-evaluation of the intervention, however, one of the three schools participating did not end up implementing the intervention. Therefore, the research team treated the non-participating school as a naturalistic control group in the analysis.[30] Further, none of the studies were blinded, leading to the overall estimation of a serious risk of bias for self-reported outcomes and a moderate risk of bias for objective outcomes.

For GRADE, the overall quality of evidence for BMI z-score and WC was very low (Table S4). The risk of bias was serious in the quality of the evidence. The concerns about inconsistency and indirectness were not serious. As we were unable to perform the meta-analysis, this was a limitation in evaluating heterogeneity. Imprecision was serious due to the small sample size.[41] The quality of evidence across studies was also downgraded due to the lack of randomization. We did not find conference abstracts or registered trials without publications, so it was unclear if small study effect was significant.

Discussion

Over the past few decades, Canada has not been immune to the global rise in pediatric obesity and T2DM. These disorders are especially prevalent in Indigenous children in Canada, so there is an urgent need to define culturally appropriate, Indigenous Knowledge-based interventions to manage obesity and T2DM.

School- or community-based interventions that integrate traditional knowledge can be especially relevant to remote communities and provide a locally sustainable care model to treat obesity and prevent T2DM. The studies evaluating obesity and T2DM prevention programs for Indigenous children in Canada were non-randomized and provided conflicting results. With these limitations in mind, non-randomized studies reported modest reductions in BMI z-score and WC compared to controls, with a very low quality of evidence.[30,31] These studies employed a peer-led component in schools, which provides a feasible, sustainable, and cost-effective solution.[30,31,42] Two uncontrolled studies reported the BMI z-score and WC outcomes with contrasting results.[36,37]

A recent scoping review aimed to identify existing school-based nutrition programs for Indigenous children in Canada and evaluate their success identified 34 unique programs addressing various health components.[18] Most of the interventions implemented educational components (56%), partnerships, such as engaging elders (59%), with 62% of the interventions being owned and led by Indigenous communities.[18]

Community- and school-based participatory research should focus on local ownership and strong community leadership and participation. The communities have the option of selecting partners that can be engaged as needed to support study design, implementation, and evaluation guided by the communities' specific goals, preferences, and values. Indigenous Knowledge and practices need to be central to research design, conduct, and evaluation and the data must be under the control of and are possessed by the community.[18,19] Understanding the needs and design of interventions directed at Indigenous children in urban settings is an area where more data are needed.

One of the strengths of this review involves the comprehensive search strategy and the inclusion of all relevant literature by expanding our searches to grey literature and reference lists. We also used iPortal, a database primarily focused on Indigenous peoples of Canada, to identify relevant studies specific to Indigenous health.[24] We also used standardized tools, including the GRADE approach to evaluate the confidence in recommendations based on the evidence.

One limitation of the review was related to the location of the study conduct. While studies primarily focused on Indigenous participants living on reserves in Northwestern Ontario, Manitoba, British Columbia, and Quebec, no studies included Indigenous children living in urban settings. As more than half of Indigenous people in Canada live in urban areas, it is crucial to define ways to create culturally appropriate interventions for these populations informed by needs, preferences, and values.[43,44]

Although four studies included a control group,[30–33] none of the studies were randomized controlled trials (RCTs), and sample sizes were small, which limits confidence in the evidence.[41] Lastly, one of the goals was to evaluate the effect of these interventions on the prevention of T2DM, and no studies reported data on T2DM prevention or changes in metabolic health parameters. Preventing and treating obesity is the most promising approach to preventing T2DM, as obesity is one of the main drivers of this complex disease.

Conclusion

In conclusion, this systematic review highlights the need for traditional knowledge-based lifestyle interventions to manage obesity in Indigenous children in Canada that may lead to improvements in body mass and adiposity measures and potentially prevent diabetes. Further research that is Indigenous-led, owned, with adequately powered RCTs that incorporate Indigenous Knowledge and ways of knowing into obesity treatment and strategies to prevent T2DM is urgently needed.

Additionally, future studies need to standardize the reporting of metabolic outcome measures and assess the impact of Indigenous Knowledge-based lifestyle interventions on preventing T2DM in urbanized Indigenous communities. As childhood obesity often tracks into adulthood,[45–49] longitudinal studies are urgently needed to measure the impact of attempts to alter the obesity trajectory in childhood that may prevent the cardiovascular and metabolic health concerns observed in Indigenous communities during adulthood.

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Disclosure

The authors declare no competing interests.

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