

ORIGINAL ARTICLE

Prediabetes: An emerging public health concern in adolescents

Shelley Spurr¹  | Jill Bally¹  | Diane Allan¹ | Carol Bullin¹ | Erick McNair² 

¹Faculty of Nursing, College of Nursing, University of Saskatchewan, Saskatoon, Saskatchewan, Canada

²Faculty of Medicine, College of Medicine, University of Saskatchewan, Saskatoon, Saskatchewan, Canada

Correspondence

Shelley Spurr, Faculty of Nursing, College of Nursing, University of Saskatchewan, Saskatoon, SK, Canada.

Email: Shelley.spurr@usask.ca

Summary

Objectives: To identify the presence of risk factors for type 2 diabetes (ethnicity, body mass index, blood glucose tolerance and blood pressure) and to determine the prevalence of prediabetes and type 2 diabetes in Canadian adolescents attending two multicultural urban high schools.

Methods: A total of 266 multicultural urban high school students who live in a mid-sized Western Canadian city, aged 14–21, were screened for risk factors of prediabetes and type 2 diabetes in March–April 2018. Data with respect to demographics, family history of diabetes, anthropometrics, blood pressure and haemoglobin A1c (HbA1c) were collected. Data analysis was done using descriptive and inferential statistics in addition to chi-square analyses.

Results: Based on body mass index, 38% of the adolescents were classified as either overweight or obese. Overweight rates for females (69.8%) were double than males (30.2%); however, males (52.2%) were more likely to obese than the females (47.8%). Based on HbA1c levels, 29.3% were at high risk to develop either diabetes or prediabetes and 2.6% were classified in the prediabetes range. Prehypertension/hypertension rates of 47% in the sample increased to 51% in those adolescents with elevated HbA1c; the majority of these prehypertensive/hypertensive participants were male.

Conclusion: High rates of overweight/obesity and prehypertension/hypertension were found in the adolescents studied and indicated the presence of prediabetes and an increased risk to develop type 2 diabetes and associated complications. Obesity and hypertension are major risk factors for developing type 2 diabetes, resulting in earlier exposure to metabolic consequences and, ultimately, long-term complications. Thus, timely research is needed to identify age-appropriate strategies that address risks and to develop recommendations for routine screening of adolescents for prediabetes.

KEYWORDS

adolescents, diabetes type 2, hypertension, obesity, prediabetes, screening

1 | INTRODUCTION

Previously considered an adult disease and non-existent in the paediatric population in the late 20th century, type 2 diabetes has now become one of the fastest growing paediatric chronic diseases worldwide.¹⁻³ A Canadian national surveillance study found an incidence of type 2 diabetes in children and adolescents of 1.54 per 100 000 per year.⁴ In the United States, estimated incidence rates have increased to an annual rate of 12.5 per 100 000 in the 10- to 19-year-old age group.⁵ As a result, this current health issue is of great interest to researchers and clinicians around the world.¹

Recent evidence suggests the development of complications with type 2 diabetes might occur more quickly in adolescents than in adults. Evidence suggests that loss of beta-cell function is accelerated in young type 2 diabetes, leading to premature development of complications, with adverse effects on quality of life and long-term outcomes.⁶ A recent study conducted in Manitoba found renal and neurologic problems manifested within 5 years of diagnosis and major complications such as dialysis, blindness and amputation within 10 years.⁷

In addition to in-depth research into the complications of type 2 diabetes in children and adolescents is the plethora of research establishing the multiple risk factors for type 2 diabetes in youth. A prominent risk factor for type 2 diabetes is obesity, with documented prevalence rates of 80% occurring at the time of diagnosis.^{6,8} Family history and ethnicity are also risk factors for type 2 diabetes. For example, adolescents from certain ethnic groups (Aboriginal, Asian, African and Hispanic) are known to be at high risk. For the purpose of this article, ethnicity is defined on the basis of cultural characteristics such as shared language, ancestry, religious traditions, dietary preferences and history.⁹ Other risk factors for the development of type 2 diabetes include insulin resistance that is manifested as acanthosis nigricans, polycystic ovarium syndrome, hypertension and dyslipidemia.^{8,10} Understanding these clinical and demographic characteristics for adolescents at risk for prediabetes and type 2 diabetes is important for developing targeted screening and intervention programmes to prevent and reduce mortality from this emerging chronic disease.⁸

Findings from our pilot study conducted in three Northern predominantly Indigenous communities in Western Canada¹¹ indicate a disconcerting rate of prediabetes (10%) in Indigenous adolescents that is significantly higher than the previously reported prevalence (1%).^{4,11,12} Other findings include high rates of overweight (22.5%), obesity (17.5%), and prehypertension or hypertension (26.6%).¹¹ This pilot study is the first to examine the prevalence of prediabetes in Canadian Indigenous adolescents living in rural and remote communities in the 21st century, and the findings underscore the need for early screening of this population for both prediabetes and type 2 diabetes. The results also illustrate that large numbers of young adolescents may remain undiagnosed or be at high risk for prediabetes and type 2 diabetes in other communities in Canada. Despite significant international attention on the chronicity of type 2 diabetes, most studies have

focused on the clinical features, treatment and complications for adolescents.^{3,8,13} The National Health and Nutrition Examination Survey found a prevalence of 0.12% undiagnosed diabetes in adolescents.³ To our knowledge, no studies other than our own pilot study that examined rural and remote living predominantly Indigenous adolescents have reported rates of prediabetes and risk for type 2 diabetes in Canadian adolescents. Therefore, these findings from the aforementioned pilot study and other research necessitate ongoing explorations with a larger multicultural investigation in urban settings. The present study is novel, as it takes a population-based research approach with a focus on earlier diagnosis (prediabetes rather than post-diagnosis) and a new population (urban-living adolescents attending two predominantly multicultural high schools in a mid-sized Western Canadian city). The research objective of this study was to generate insight into the risk factors and prevalence of prediabetes and type 2 diabetes in adolescents living in a mid-sized Western Canadian city. This research was guided by the following questions:

1. Are the following risk factors present in adolescents attending two predominantly multicultural Canadian urban secondary schools: ethnicity, body mass index, blood glucose tolerance and blood pressure?
2. What are the prevalence rates of prediabetes and type 2 diabetes in adolescents attending two predominantly multicultural Canadian urban secondary schools?

2 | METHODS

This study was approved by the biomedical ethics research committee at the University of Saskatchewan, the school district and the principals of the participating schools. A letter and consent form were sent home to inform parents of the purpose and procedures of the study, the storage of data, confidentiality and the right to withdraw. The principal investigator (PI) visited the classrooms to explain the study and invite the adolescents to participate, including details of the diabetes screening. Students were reassured that they were not required to participate and refusal would not jeopardize their course standing. Parental consent and student assent were obtained from each participant with the exception of adolescents over the age of 18, who were given permission by the ethics board and school district to consent to the screening.

2.1 | Study design

In the present exploratory quantitative study, participants were screened for identification of risk for prediabetes and type 2 diabetes through the collection of demographic data, family history, anthropometric measurements, blood pressure (BP) and haemoglobin A1c (HbA1c) blood glucose. Similar protocols were used in the team's pilot study.¹¹

2.2 | The sample

High school students ($n = 266$) from two urban high schools in a mid-sized western Canadian city were assessed for risk for prediabetes and type 2 diabetes. Details of the response rates for both sites are outlined in Table 1. The qualifying criteria for participation in the diabetes screening included adolescents ($n = 266$) who were 14-21 years old, enrolled in at least one class at the participating high schools, and present on the day of data collection. Exclusion criteria were non-English speaking or unable to provide consent as determined by the Registered Nurse (RN) on initial contact.

2.3 | Procedures

The principals requested that the screening be conducted during the lunch hour. To ensure consistency, the principal investigators (PIs)

and three RNs conducted the diabetes screening. The students were first called down to the main office, and then, the PI collected the consent forms prior to the assessment. To maintain confidentiality, students were assigned a qualifying number. The assessments were conducted in a quiet room within the high school over a 2-month period in the spring of 2018.

2.4 | Anthropometry, blood pressure and diabetes measurements

As recommended by Diabetes Canada,¹⁴ anthropometrical measurements including weight and height were assessed and these measurements then used to calculate body mass index (BMI) and to classify students as normal, overweight or obese according to the Center for Disease Control growth charts.¹⁵ For those students under 20 years of age, BMI was interpreted as standard deviations and percentiles in relation to age and sex. Following World Health Organization guidelines, those with a BMI >1 standard deviation for their age were considered overweight and those with a BMI >2 standard deviations for their age were considered obese. For those who were 20 years old, a BMI of 25 or above was classified as overweight and of 30 or above considered obese.¹⁶

An auscultated blood pressure was measured by an RN using a standard clinical sphygmomanometer. As recommended by the National Institutes of Health¹⁷ for adolescents 17 years or younger, hypertension was defined as a diastolic blood pressure at or above the 95th percentile for sex, age and height. Those with a systolic or diastolic measure at or greater than the 90th percentile but less than the 95th percentile were considered to have prehypertension. For those who were ≥ 18 years old, abnormal increases in BP were defined as follows: mean SBP ≥ 140 mm Hg or DBP ≥ 90 mm Hg was high/hypertensive and mean SBP of 130-139 mm Hg and/or a DBP of 85-89 mm Hg was prehypertensive.¹⁸ As recommended by the National Institutes of Health,¹⁷ BP was measured twice at the same visit if it was elevated. Participants with two confirmed elevated BPs were screened again on a subsequent visit and in such cases, the averages of the systolic and diastolic measurements were used. Any adolescent with two elevated BP measurements was referred to their physician for follow-up.

A haemoglobin A1c (HbA1c) point of care test was used to assess blood glucose levels. HbA1c reflects the average blood glucose level during the preceding 2-3 months rather than the daily variations in blood glucose levels and is a reliable and sensitive screening test for children and adolescents.¹⁹ A validated Cobas HbA1c test assay that is standardized to the National Glycohemoglobin Standardization Program Roche Diagnostics²⁰ was used; this diagnostic test system is designed to quantitatively determine the % haemoglobin in human capillary blood. An estimated average glucose level is calculated with the Cobas b101 system. Prior to use, the system was tested for quality control as indicated by the Roche training guide. Adolescents were classified as at increased risk for developing diabetes, pre-diabetic and type 2 diabetic with levels of HbA1C of 5.5%-5.9%, 6.0%-6.4%, and above 6.5%, respectively.^{21,22} All participants who

TABLE 1 Demographics

	Site 1		Site 2		Total	
	N	%	N	%	N	%
Response rate	94	39	172	33	266	35
Gender						
Male	44	46.8	70	40.7	114	43
Female	50	53.2	102	59.5	152	57
Ethnicity						
Indigenous	20	21.2	11	6.4	31	12
European	2	2.1	34	19.8	36	14
Asian	42	44.7	73	42.2	115	43
Caucasian	12	12.8	34	19.8	46	17.4
African	17	18.1	10	5.8	27	10
Central American	0	0	3	1.7	3	1.1
South American	0	0	1	0.6	1	<1
Middle Eastern	0	0	6	3.5	6	2.2
Age						
14	0	0	1	0.6	1	<1
15	4	4.3	9	5.2	13	5
16	26	27.7	27	15.7	53	20
17	27	28.7	81	47.1	108	41
18	28	29.8	45	26.2	73	27
19+	9	9.6	9	5.2	18	6.7
Family history of diabetes						
Yes	42	44.7	80	46.5	122	46
No	49	52.1	89	51.7	138	52
Unknown	3	3.2	3	1.7	6	2.2
Exposure to diabetes in utero						
Yes	4	4.3	4	2.3	8	3
No	86	91.5	89	46.5	175	66
Unknown	4	4.3	3	1.7	7	2.6

tested above 5.9% were referred to their family physician for follow-up and additional testing. Additionally, RNs met individually with any adolescents who tested in the high-risk range to inform them of their results and answer any questions.

As recommended by Diabetes Canada (2018), other risks factors for the development of type 2 diabetes included in the screening were demographic data (high-risk populations are people of African, Arab, Asian, Hispanic, Aboriginal or South Asian descent), a history of diabetes in a first- or second-degree relative, and maternal gestational diabetes.¹⁴ Specifically, the adolescents were asked about their age, sex, ethnicity, personal medical history of diabetes and if they were exposed to diabetes in utero.

2.5 | Analysis

Descriptive and inferential statistics were computed using the Statistical Package for Social Sciences (IBM® SPSS v.22.0, Armonk, NY, USA) to establish risk and prevalence rates for prediabetes and type 2 diabetes in the adolescent sample. Further, chi-square analyses were conducted to investigate if the risk factors of hypertension, obesity and family history occurred at higher frequencies for males and females who presented with an increased HbA1c level.

3 | RESULTS

A total of 266 adolescent participants were screened for prediabetes and type 2 diabetes. The sample had a similar representation of male (N = 114) and female (N = 152) participants ranging in age from 14 to 21 years (mean 17.16). Demographic data, exposure to a diabetic pregnancy, family history and ethnicity are reported in Table 1.

3.1 | Ethnicity

Due to the multicultural nature of the schools, participant ethnicity varied greatly with the largest number of adolescents self-identifying as Asian (43%), Caucasian (17%), European (14%) and Aboriginal

(12%). Many participants self-identified as Canadian as their families had been in living in Canada for many years. However, when asked more about their past family history, they were able to specify their ethnicity. The percentage of each ethnicity is reported in Table 1.

3.2 | Body mass index

Body mass index for the overall population ranged from 16.6 to 45.8 (mean 24.18). Overall, 62 (n = 167) of adolescents were categorized as normal weight, 20% (n = 53) as overweight and 18% (n = 46) as obese (Figure 1). Overweight rates for females (69.8%) were double than males (30.2%); however, males (52.2%) were more likely to obese than the females (47.8%). Chi-square analyses indicated no statistically significant differences in terms of gender.

3.3 | Blood pressure measurements

Manual blood pressure measurements were conducted. Slightly more than half (53%) of the adolescent participants were classified in the normal range, with notable rates of prehypertension (20%) and hypertension (27%). Blood pressure classification for the overall population by gender is reported in Figure 2. A higher number of males (58%) were classified with prehypertension and hypertension than females (42%, $\chi^2 = 7.63$, $df = 2$, $P = 0.022$).

3.4 | Blood glucose tolerance

HbA1c levels ranged from 4.3% to 6.4% (mean 5.34%). Overall, 68.1% (n = 181) of adolescents were categorized as having normal HbA1c levels, 29.3% (n = 78) were assessed to have increased HbA1c levels and were considered high risk (5.5%-5.9%), and 2.6% (n = 7) were classified in the prediabetes range (6.0%-6.4%). A total of 32% (n = 85) of the adolescents presented in the high-risk or prediabetes category with higher prevalence in females (54.1%, n = 46) than males (45.9%, n = 39); no statistically significant differences were found between male and female participants with increased HbA1c levels.

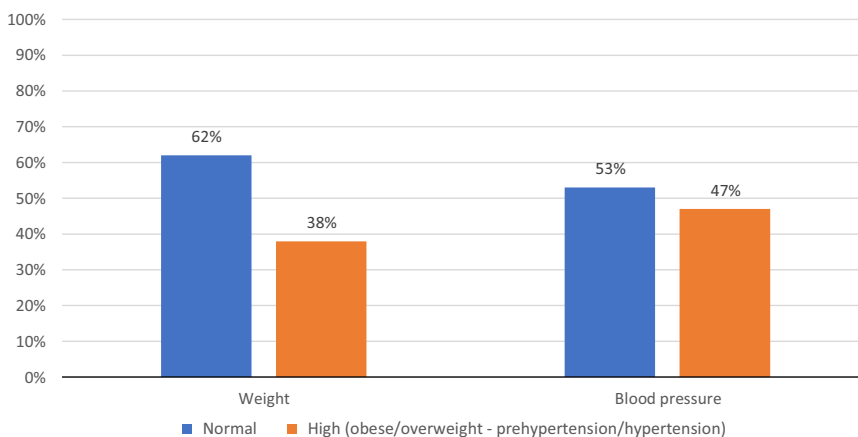


FIGURE 1 Weight and blood pressure for those with normal HbA1c

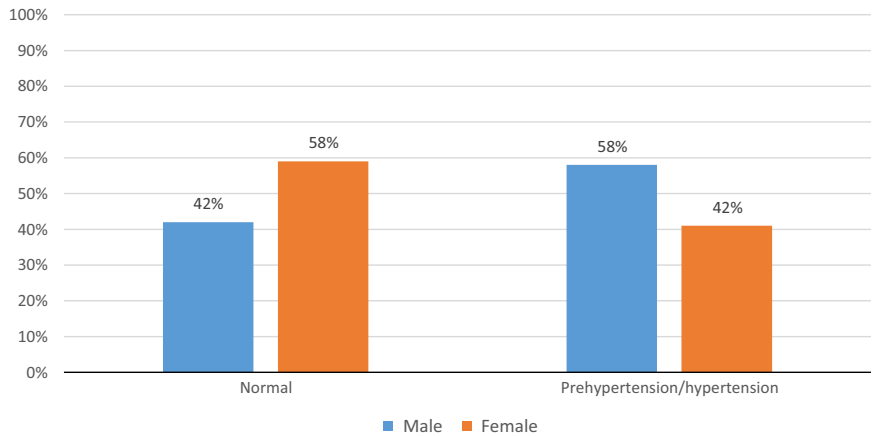


FIGURE 2 Blood pressure by gender

3.5 | Blood pressure, family history and weight classification for participants with an elevated HbA1C level

Participants with increased HbA1c levels were categorized in the high-risk or prediabetes HbA1c range (5.5%-5.9% and 6.0%-6.4%) were also likely to be overweight/obese (36%) and prehypertensive/hypertensive (51%; Figure 3). When gender difference was analysed, higher numbers of females (20%) presented as overweight and/or obese than males (16%). Also notable from this analysis is the large number of females (22%) and males (28%) with prehypertension/hypertension. Over half of the participants (51.9%) classified as either high risk or in the prediabetes range had a family history of diabetes. On the other hand, only a few adolescents (31.1%) who had previous exposure to a diabetes in utero had elevated HbA1c. Chi-square analysis indicated no significant differences between the percentages of male and female students who presented with elevated HbA1c levels and were classified as overweight/obese and prehypertensive/hypertensive.

4 | DISCUSSION

The main finding of this study is that Canadian adolescents are at significant risk of prediabetes and type 2 diabetes. First, more than

one-third of the adolescents (38%) evaluated in this study were classified as overweight or obese. Obesity is a major risk factor for developing type 2 diabetes and remains prevalent in children and adolescents in Canada.^{4,23} Results from the Canadian Health Measures Survey (2009-2011) show that the prevalence of overweight (19.8%) and obesity (11.7%) in youth has not increased over the last decade but the estimated overall prevalence in youth aged 12-17 years remains high (31.5%). Sex differences indicate females ages 12-17 are more likely to be overweight (20.9% vs 18.9%) and males are more likely to be obese (10.7% vs 9.6%).²³ The results of the present study confirm the trend of overweight/obesity in Canadian adolescents, and specifically, that females are more likely to be overweight and males more likely to be obese. Given the negative health outcomes associated with overweight and obesity, these findings highlight a continuing public health concern.^{19,23}

A second important finding is the prevalence rates of undiagnosed adolescents who are either high risk to develop diabetes (29.3%) or in the range of prediabetes (2.6%). Similar to previous published prevalence rates of type 2 diabetes, the present study found a predominance of females in these categories.^{8,10} The prevalence of prediabetes has been investigated in various countries across the world, including Mexico (1.5%), UAE (5.4%) and China (0.28%).²⁴⁻²⁶ The studies emerging from the United States and Canada focus on adolescents who have been diagnosed with

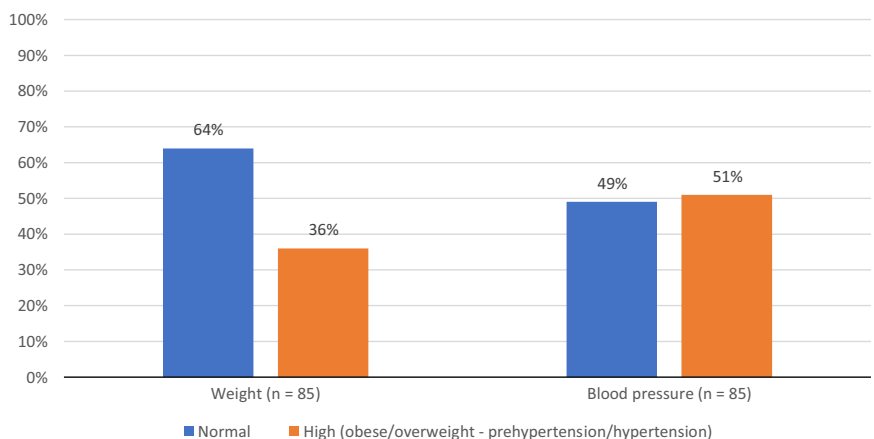


FIGURE 3 Weight and blood pressure for those with elevated HbA1C

diabetes or present findings that estimate the prevalence of pre-diabetes and/or undiagnosed diabetes.^{8,27-29} In the present study, community-based screening was undertaken to determine the number of Canadian adolescents who were in the “at risk” or pre-diabetes and type 2 diabetes blood glucose range. A HbA1c level of 6.0%-6.4% is associated with a highly increased risk (20%-25%) of the incidence of type 2 diabetes within 5 years.^{22,30} In addition, evidence is accumulating to indicate that type 2 diabetes has a more aggressive disease phenotype in youth, leading to premature development of complications that have serious effects on quality of life.^{6,7,31,32} Earlier onset hyperglycaemia leads to a longer lifetime exposure to the metabolic consequences of the disease and greater propensity for long-term complications.^{6,32} However, lifestyle modifications can reverse the prediabetic state and could save the patient and the healthcare system significant costs, but this clearly requires discovery of prediabetes status among at-risk patients.^{29,33} Therefore, these unique findings related to the prevalence of adolescents who are in the “at risk” and prediabetes range truly underscore the importance of early screening and intervention to prevent this disease.

Another significant finding is the rates (36%) of overweight/obesity in adolescents who present with elevated HbA1c levels, with females being more likely to overweight than males. Research in general adolescent populations in Canada reports a similar prevalence (30%) of overweight/obesity to that reported here and, more specifically, that rates of overweight are greater among females than males.²³ The present study results are concerning due to the emerging evidence that illustrates an increase in surrogate markers for the risk for type 2 diabetes and cardiovascular disease in obese children and adolescents.^{1,4,6} Given the grievous complications associated with type 2 diabetes, and the female predominance of type 2 diabetes (2:1),⁸ these findings highlight the need for robust prevention programmes designed to prevent overweight/obesity in children and adolescents with strategies specifically targeting female children.

The third risk factor presenting in this population is rates of prehypertension or hypertension (47%), with significant findings indicating boys are more likely to have prehypertension or hypertension. Increased blood pressure (51%) among those adolescents with elevated HbA1C is also disconcerting. These rates are double those from a recent Canadian study that found a rate of 28% in adolescents (males and females) at the time of diagnosis of type 2 diabetes.⁴ Other American studies found similar rates of 20%-30% at initial presentation.^{10,34} Hypertension can lead to many serious micro and macro vascular problems such as retinopathy, neuropathy, diabetic kidney disease and myocardial infarction,¹⁰ and often clusters with other cardio-metabolic comorbidities such as obesity and hyperglycaemia.¹⁷⁻¹⁹ All of these factors have the potential to increase the risk of cardiovascular disease and adverse health outcomes. The elevated rates of prehypertension/hypertension in adolescents are a new and unique finding. Higher rates in males of prehypertension/hypertension illustrate the need to explore possible gender differences. As such, effective strategies aimed at preventing elevated

blood pressures and the development of other comorbidities such as prediabetes and type 2 diabetes are essential.

4.1 | Limitations

The study was conducted on a modest sample from one Western Canadian province. However, due to the multicultural nature of the school communities, the sample was representative of an urban adolescent population and the results appear congruent with other research findings.^{10,23} Future research studies are needed with a larger sample that is representative of other Canadian provinces to further validate the results. The requirement to conduct the screening during the noon hour might have limited the sample as some adolescents chose to forgo the screening rather than miss their lunch break.

5 | CONCLUSION

Many adolescents were found to be “at risk” for diabetes. Some youth were already categorized in the prediabetes range, making these individuals at even higher risk for developing type 2 diabetes and its complications. In addition, high rates of overweight and obesity were confirmed in the adolescent females and males, respectively. Finally, the proportion of adolescents with prehypertension and hypertension was notably high. Research directed at identifying age-appropriate interventions is urgently needed to slow the emerging epidemic of type 2 diabetes and associated comorbidities such as obesity and hypertension in adolescents.

ACKNOWLEDGEMENTS

The researchers thank the many adolescents who participated in this study, as well their families who granted permission for their participation. We are also grateful to the Greater Saskatoon Catholic School Board for their continued support.

CONFLICT OF INTEREST

Nothing to declare.

ETHICAL APPROVAL

This study was approved by the University of Saskatchewan Biomedical Research Ethics Board and the Greater Saskatoon Catholic School Board, Canada.

AUTHOR CONTRIBUTION

SS and JB participated in the study design, data collection and analysis, wrote and revised the manuscript, and contributed to the discussion. DB conducted the data analysis, revision of the manuscript and contributed to the discussion. CB and EM assisted with data collection, wrote and revised the manuscript, and contributed to the discussion.

DATA ACCESSIBILITY

The data are fully accessible to the researchers and are stored in a secured location at the University of Saskatchewan, Canada.

ORCID

Shelley Spurr  <https://orcid.org/0000-0001-6009-0368>

Jill Bally  <https://orcid.org/0000-0003-2670-9109>

Erick McNair  <https://orcid.org/0000-0003-0931-8560>

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How to cite this article: Spurr S, Bally J, Allan D, Bullin C, McNair E. Prediabetes: An emerging public health concern in adolescents. *Endocrinol Diab Metab*. 2019;2:e00060. <https://doi.org/10.1002/edm2.60>