Evaluating health disparities in a pediatric population with type 1 diabetes in Quebec

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Abstract

BACKGROUND: Few Canadian studies have examined the relationship between socioeconomic status (SES) and glycemic control while considering other equity measures such as ethnicity, immigration, and other factors that modify the relationship between SES and glycemic control.

OBJECTIVE: My main objective was to determine the association between SES and glycemic control (HbA1c) in children ages 0-18 years with type 1 diabetes (T1D) followed at the Montreal Children's Hospital (MCH). My secondary objectives were to 1) determine whether insulin pump use, processes of care (number of diabetes-related clinic visits), and depression were effect modifiers of this relationship and 2) to determine the association between ethnicity and/or immigration status with mean HbA1c.

METHODS: Retrospective cohort study using MCH's Pediatric Diabetes Database with data on children ages 0-18 years with T1D. A Diabetes Clinical Intake Form was used for demographic information such as ethnicity, immigration status, and depression. We included children diagnosed with T1D for at least a year with an index visit between November 1st, 2019 and October 31st, 2020. The main outcome was mean HbA1c in the year following the index visit. The main exposure was SES measured by the Material and Social Deprivation Index. SES was also measured by the Canadian Index of Multiple Deprivation (CIMD) which examines residential instability, situational vulnerability, economic dependency, and ethnocultural composition (a measure of ethnic density). SES was defined as Q1-Q2 (least deprived), Q3 (moderately deprived), and Q4-Q5 (most deprived). I used multivariable linear regression to determine the association between SES and mean HbA1c adjusting for age at index date, sex, diabetes duration, insulin pump use, and processes of care. Effect modification by insulin pump, processes of care (number of diabetes-related clinic visits in the past year), and depression was assessed with interaction terms in three separate regression models. We used multivariable linear regression analysis to determine the association between ethnicity, immigration and mean HbA1c adjusted for SES, age, sex, diabetes duration, insulin pump use, and processes of care.

RESULTS: A total of 203 children were included in the main analysis. Mean age was 13.5 years; 53.2% males, and mean diabetes duration was 4.9 years. The sample consisted of 47.3%, 26.6%, and 26.1% in the least, moderately, and most deprived quintiles, respectively. Children in

the most deprived quintiles had a higher mean HbA1c compared to those in the least and moderately deprived (p=.05). In the adjusted analysis, HbA1c in the most deprived quintiles was 0.5% higher compared to the least deprived (95% Confidence Interval (95% CI) 0.05-0.97). Effect modification by insulin pump, processes of care, and depression was not significant. The CIMD assigned quintiles for 208 children. The ethnocultural composition was associated with lower mean HbA1c in moderately and most diverse quintiles compared to least diverse quintiles (β =-1.1, 95% CI -1.9, -0.4, β=-0.8, 95% CI -1.5, -0.2). In terms of ethnicity, the racialized compared to the non-racialized group had a higher mean HbA1c (β=0.7, 95% CI 0.2-1.2).

DISCUSSION: Consistent with previous findings, lower SES was associated with higher HbA1c; effect modification by insulin pump, processes of care, and depression was not observed. We observed ethnic disparities in HbA1c levels, which is consistent with previous data from the UK and the U.S. Although the racialized compared to the non-racialized group was associated with higher HbA1c, the most diverse compared to the least diverse neighborhood-level ethnocultural composition was associated with lower mean HbA1c. This suggests that other health-promoting factors in areas of high ethnocultural composition may affect HbA1c, such as social cohesion and community support.

CONCLUSION: The associations between SES and glycemic control are important for further research to understand drivers that contribute to disparities in a Canadian context.

Résumé

CONTEXTE: Peu d'études canadiennes ont examiné la relation entre le statut socioéconomique (SSE) et le contrôle glycémique en considérant l'ethnicité, l'immigration et d'autres facteurs qui modifient la relation.

OBJECTIF: Objectif principal : déterminer la relation entre le SSE et le contrôle glycémique (HbA1c) des enfants de 0 à 18 ans atteints de diabète de type 1 (DT1) et suivis à l'Hôpital de Montréal pour enfants (HME). Objectifs secondaires : 1) déterminer la modification d'effet de la relation par la pompe à insuline, les processus de soins (nombre de visites à la clinique) et la dépression 2) déterminer l'association entre l'ethnicité ou l'immigration et l'HbA1c.

MÉTHODES: Étude rétrospective utilisant la base de données du diabète pédiatrique de L'HME. Un formulaire d'admission a permis la collecte d'information démographique (ethnicité, immigration, dépression). Les enfants de 0 à 18 ans atteints du DT1 depuis $\geq$1 an et ayant une visite entre le 1er novembre 2019 et le 31 octobre 2020 étaient inclus. Le résultat principal était l'HbA1c dans l'année suivant la visite d'index. L'exposition principale était le SSE mesuré par l'indice de défavorisation matérielle et sociale. Le SSE a aussi été mesuré par l'indice canadien de défavorisation multiple (ICDM) qui inclue l'instabilité résidentielle, la vulnérabilité situationnelle, la dépendance économique et la composition ethnoculturelle. Le SSE était défini comme Q1-Q2 (moins défavorisé), Q3 (modérément défavorisé) et Q4-Q5 (plus défavorisé). Une régression linéaire multiple a déterminé l'association entre le SSE et l'HbA1c en ajustant pour l'âge, le sexe, la durée du diabète, la pompe à l'insuline et les processus de soins. La modification d'effet par la pompe à insuline, les processus de soins et la dépression a été évaluée à l'aide de termes d'interaction dans 3 modèles distincts. Une régression linéaire multiple a déterminé l'association entre l'ethnicité, l'immigration et l'HbA1c ajustant pour le SSE, l'âge, le sexe, la durée du diabète, la pompe à l'insuline et les processus de soins.

RÉSULTATS: 203 enfants ont été inclus dans l'analyse principale. L'âge moyen était de 13.5 ans, 53.2% étaient males et la durée moyenne du diabète était de 4.9 ans. Le groupe comprenait 47.3%, 26.6% et 26.1% d'enfants dans les quintiles les moins, modérément et les plus défavorisés, respectivement. Les quintiles plus défavorisés avaient des valeurs d'HbA1c plus élevées que les quintiles les moins et modérément défavorisés (p=.05). Dans l'analyse ajustée, l'HbA1c des quintiles les plus défavorisés était 0.5% supérieur à celui des moins défavorisés (IC 95%, 0.05-0.97). La modification de l'effet par pompe à insuline, les processus de soins et la

dépression n'était pas significative. L'ICDM a attribué des quintiles pour 208 enfants. La composition ethnoculturelle était associée à des valeurs d'HbA1c inférieurs dans les quintiles modérément et les plus diversifiés par rapport aux quintiles les moins diversifiés (β=-1.1, IC 95% -1.9,-0.4, β=-0.8, IC 95% -1.5,-0.2). Selon l'ethnicité, le groupe racialisé par rapport au groupe non racialisé avait des valeurs d'HbA1c plus élevée (β=0.7, IC 95% 0.2-1.2).
DISCUSSION: Comme les études courantes, un SSE inférieur était associé à un taux d'HbA1c plus élevé; la modification de l'effet par la pompe à insuline, les processus de soins et la dépression n'a pas été observée. Il existe des disparités ethniques dans l'HbA1c, ce qui est cohérent avec les données précédentes au Royaume-Uni et aux États-Unis. Bien que le groupe racialisé par rapport au groupe non racialisé présentait un HbA1c plus élevé, la composition ethnoculturelle la plus diversifiée était associée à un taux d'HbA1c plus bas. Ceci suggère que d'autres facteurs de santé dans les zones à haute densité ethnique peuvent affecter l'HbA1c, tels que la cohésion sociale et le soutien communautaire.
CONCLUSION: Les résultats de l'association entre le SSE et le contrôle glycémique sont importants pour mieux comprendre les facteurs qui contribuent aux disparités dans le contexte canadien.

Contributions

As first author, I, Suzanne Simba was responsible for elaborating the research questions, hypothesis, statistical analysis, data interpretation, and drafting the manuscript. My supervisors, Dr. Meranda Nakhla and Dr. Patricia Li provided guidance throughout the thesis and contributed significantly in the conceptualization of the methodology, formulation of research questions, study design, interpretation of findings, as well as revising and providing constructive feedback.

All chapters of this thesis were written by Suzanne Simba and critically reviewed and revised by Dr. Meranda Nakhla, Dr. Patricia Li, Dr. Elham Rahme, and Dr. Julia Von Oettingen.

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List of Abbreviations /Acronyms

Abbreviation	Meaning
ADA	American Diabetes Association
BGM	Blood glucose monitoring
CGM	Continuous glucose monitoring
CI	Confidence interval
CIMD	Canadian Index of Multiple Deprivation
CSII	Continuous subcutaneous insulin infusion
DKA	Diabetic ketoacidosis
HbA1c	Glycated hemoglobin
INSPQ	Institut National de Santé Publique du Québec
ISPAD	International Society for Pediatric and Adolescent Diabetes
MCH	Montreal Children's Hospital
MDI	Multiple daily injections
MSDI	Material and Social Deprivation Index
OR	Odds ratio
PCCF	Postal Code Conversion File
PHQ-2	Patient Health Questionnaire
SD	Standard deviation
SDOH	Social determinants of health
SES	Socioeconomic status
T1D	Type 1 diabetes
T2D	Type 2 diabetes

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1 BACKGROUND

1.1 Descriptive epidemiology of T1D

Type 1 diabetes (T1D) is one of the most common chronic diseases of childhood accounting for over 85% of all diabetes cases in youth under 20 years old worldwide.[1,2] T1D results from an autoimmune disorder leading to the destruction of pancreatic beta-cells and the subsequent lack of insulin.[1,3] The worldwide incidence and prevalence of T1D vary largely. The highest incidences of T1D reported by the most recent International Diabetes Federation Atlas (10th edition) was in Europe including Sardinia, Finland, Sweden, Norway, Portugal, United Kingdom (UK) with over 20 cases per 100,000 per year[2,4] as well as Middle Eastern and Northern African countries including Saudi Arabia, Algeria, Qatar and Kuwait, with an age-standardized incidence of over 30 cases per 100 000 per year in children ages 0-14 years.[5] Higher incidences are also reported in Pacific countries including Australia and New Zealand with rates between 10 and 30 cases per 100 000 per year.[5] Lower rates are reported in Asian countries such as China, Singapore, and Japan with rates less than 10 cases per 100 000 per year and in Central and South America, with an age-adjusted incidence of less than 20 cases per 100,000 per year in children ages <14 years.[5] In North America, the incidence reported in the United States (U.S.) was between 20 to 30 cases per 100,000 per year and more than 30 cases per 100 000 per year in Canada since 2015.[5]

Studies have demonstrated that factors such as age and ethnicity are associated with the incidence of T1D.[2] The World Health Organization Multinational Project for Childhood Diabetes (DIAMOND) project reported that in Europe between 1990 to 1999, the highest and the most substantial increase in the incidence of T1D was in children younger than 5 years.[6] Although autoimmune disorders often affect females more than males, sex differences in T1D incidence are not seen, and as demonstrated in the SEARCH for Diabetes in Youth (SEARCH) study[4] from the U.S., similar increases in T1D incidence were seen in males and females between 2001 to 2009.[7]

Ethnic differences in both incidence and prevalence of T1D have been observed.[8] In the SEARCH study, from 2001 to 2009, non-Hispanic White youth had the highest prevalence of T1D, with a prevalence of 2.55 per 1000 in 2009, followed by Black (1.62 per 1000) and

Hispanic youth (1.29 per 1000), and the lowest prevalence was found in American Indian Youth (0.35 per 1000).[8] Reports from the same database also revealed that the incidence rates of T1D in the non-Hispanic White population are among the highest in the world in youth <20 years. Specifically, the prevalence was 2.0 per 1000, and the incidence 23.6 per 100,000.[2]

Compared to other geographical regions, Canada is ranked 8th for T1D incidence.[9] Results from a sample of Canadian children and youth in British Columbia showed that the incidence rate from 2002 to 2003 was 23.3 cases per 100,000 population, and 27.3 cases per 100,000 population from 2012 to 2013, which represents an increase of 1.7% between the two periods.[10] Incidence was highest in the 5–9-year-old and 10–14-year-old age group, and a significant increase was only seen in the 10–14-year-old group. In Montreal, Quebec, the relative annual T1D incidence increased by 5.4% between 2002 to 2010 among children aged 1 to 15 years.[11] T1D incidence was highest in children aged 5 to 11 years.

1.2 Diagnosis

Symptoms of T1D include increased thirst and urination (polydipsia and polyuria), bedwetting (enuresis), weight loss, behavioural disturbance and blurred vision.[4] In severe cases when symptoms are not detected or there is a delay in diagnosis of T1D, youth present with diabetic ketoacidosis (DKA), an avoidable but potentially life-threatening complication. Between 13-80% of children worldwide are hospitalized for DKA at the time of diagnosis.[12] DKA at diagnosis is more common in younger children (<2 years) as a consequence of delayed treatment or a diagnostic error and is most common in ethnic minorities and those who have limited access to medical care.[13] Results from the SEARCH study showed that the prevalence of DKA at diagnosis has been increasing from 35.3% in 2010 to 40.6% in 2016 in the U.S.[14] Similarly, a population-based cohort study in children living in Quebec found that 25.6% of children presented with DKA at diagnosis during a study period from 2001 to 2014, with a relative increase of 2.0% per year (rate ratio 1.02; 95% Confidence Interval (95% CI) 1.01, 1.03).[15] However, multicenter data of children and adolescents from Germany and Austria between 1995 and 2009 demonstrated that although rates of severe hypoglycemia and hypoglycemic coma significantly decreased over the period, rates of hospitalized DKA remained stable, with an adjusted rate ratio per year of 1.02 (95% CI 0.99, 1.06).[16]

Furthermore, recent studies in Australia and the U.S. have reported sociodemographic differences in DKA rates, where factors such as insurance status, census poverty rate and deprivation level were associated with DKA episodes.[17,18]

1.3 Management

1.3.1 Insulin Treatments

To prevent the chronic complications of T1D (e.g., nephropathy, retinopathy), optimal glycemic control, as measured by hemoglobin A1c (HbA1c) is needed.[19] This is best achieved by an intensive insulin regimen meant to provide basal and bolus insulin, thus mimicking normal physiological patterns.[20] The administration of basal insulin controls blood glucose levels while fasting or between meals, while bolus insulin is given to control blood glucose levels with food intake. The basal-bolus approach is done by either multiple daily injections (MDI) or by continuous subcutaneous insulin infusion (CSII; insulin pumps).

MDI provides long-acting insulin for basal insulin and rapid-acting insulin before meals, which requires multiple injections throughout the day, adjusted to match carbohydrate intake in each meal.[1] Over the past decade, the use of insulin pumps has been on the rise as an alternative to MDI.[21] With insulin pump therapy, a portable pump continually administers rapid-acting insulin at a slow rate throughout the day through a catheter inserted in subcutaneous tissue and infuses additional bolus doses programmed by the patient before meals or to correct hyperglycemia.[22]

Studies in children comparing MDI to insulin pump therapy have not consistently found differences in HbA1c in all ages. A multicentre randomized controlled trial from over a decade ago involving children and adolescents followed from onset of T1D to 24 months after diagnosis reported that there was no significant difference in glycemic control between the MDI and insulin pump treatments although treatment satisfaction was higher among insulin pump users,[23] similarly to a qualitative study, where parents have reported more flexibility and less stress related to child care with insulin pump use.[24] However, a recent study using registry data suggest that insulin pumps have been effective in preventing recurrent DKA, improving glycemic control, and preventing severe hypoglycemia in preschool children compared to MDI.[25]

As insulin pumps shift towards becoming a preferred treatment of T1D, some sociodemographic differences are associated with the use of insulin pumps such as older age,

female gender, ethnicity, and socioeconomic status (SES).[26] In the SEARCH study, results showed that insulin pumps were more likely to be used by children in the non-Hispanic White ethnic group, and families with higher income and education.[26] Similarly, national data from The Virtual Diabetes Register in New Zealand between September 1, 2012, and December 31, 2018, showed that individuals of all ages living with T1D of non-European ethnicity and low SES were underrepresented among insulin pump users between 2012 and 2018, since the introduction of partial public-funding in September 2012.[27]

1.3.2 Access to Treatments

Despite the known benefits of insulin pumps, the high cost of this technology (~$8000-10,000 CAD) and its associated supplies (~$4000 CAD per year) is a barrier to accessing pumps for many Canadians living with T1D.[28] As a result, provinces across Canada implemented financial programs to cover the costs of insulin pumps and partial to complete financial coverage for associated supplies. For example, since 2006 the Ontario Ministry of Health and Long-term Care in collaboration with the Assistive Devices Program provides financial coverage for insulin pumps to those without private insurance; however, the program only provides partial coverage for supplies, the cost of which may still be prohibitive for families living with T1D.[29] In Quebec, the insulin pump access program was launched in 2011 and offers complete financial coverage for both insulin pumps and supplies.[30] Nevertheless, studies have reported SES disparities in pump uptake in jurisdictions that provide universal funding. For example, Shulman et al. reported that pump users were more likely to be of higher SES in a cohort of 7076 children from Ontario, Canada.[29] Among pump users (n=3700), 29.6% were in the highest income quintile status compared to 19.1% among non-pump users (n=3376; $p<0.05$). The observational population-based study used survey data from pediatric diabetes centers and administrative databases. Because the study lacked clinical data from medical charts, pump use was determined based on applications for pump funding at each pediatric centre, which may have misclassified pump use (e.g. those who discontinued).[29]

1.3.3 Blood glucose monitoring

Continuous glucose monitoring (CGM) systems may be used with MDI or insulin pumps to monitor blood glucose levels in real-time. CGM are wearable devices that track blood glucose levels every few minutes, throughout the day and night. A CGM has a small disposable sensor with a small subcutaneous catheter worn under the skin that tests blood glucose levels every few

minutes. Two types of CGM systems exist where glucose information is either sent continuously to a remote receiver or smart phone or requires a direct scan by a reader or smart phone (i.e., flash glucose monitoring systems). CGM use has been associated with better glycemic control, lower rates of DKA and lower rates of severe hypoglycemia in pediatric patients included in the T1D Exchange Clinic Registry in the U.S.[31] However, children with private insurance and non-Hispanic White children were more likely to use CGM compared to those with public insurance and those who are non-Hispanic Black or Hispanic.[31] Moreover, studies of children and adults with T1D have highlighted existing SES disparities in CGM.[32] For example, in a retrospective cohort study of children and adults with T1D, higher SES and private insurance were significantly associated with CGM use, which was associated with fewer diabetes adverse outcomes.[33]

1.3.4 Chronic complications

Optimal glycemic control is essential to prevent the onset and progression of microvascular and macrovascular complications.[19] Microvascular complications include eye disease (retinopathy), nerve damage (neuropathy), and kidney disease (nephropathy) while macrovascular complications include cardiovascular complications.[2] Optimal glycemic control with intensive insulin treatment, such as MDI or insulin pump therapy reduces the risks of these complications. [34]Although these complications are rare in children and adolescents, chronic complications due to T1D are an important cause of morbidity and mortality in adults with T1D due to longstanding sub-optimal glycemic control that frequently starts in childhood and adolescence.[35]

1.3.5 Diabetes management

The 2018 Diabetes Canada Clinical Practice Guidelines outline evidence-based recommendations for the prevention and management of diabetes in Canada. This includes guidance for education, glycemic targets, and treatment plans that are specific to children and adapted to a Canadian health care context.[36] The guidelines specify that patients should receive diabetes education and management in an outpatient setting.[36] Optimal adherence to guidelines has been defined as at least 3 diabetes-related physician visits/year, at least 3 HbA1c tests/year, 1

glucagon prescription dispensed/year, and appropriate screening for diabetes-related comorbidity and complications such as eye, kidney, and thyroid disease.[37] This definition was developed based on the 2008 Canadian Diabetes Association Clinical Practice Guidelines, the American Diabetes Association (ADA) Standards of Care in Diabetes, and the 2009 International Society for Pediatric and Adolescent Diabetes (ISPAD) Clinical Practice Consensus Guidelines, followed by a survey of pediatric endocrinologists across Canada consisting of an informal consultative process.[37] Additionally, access to an experienced pediatric diabetes health care team is recommended to children and families to be provided with the necessary skills, knowledge, and specialized care to manage the disease.[38] Diabetes care teams include a pediatric endocrinologist and diabetes educators; including nurses, dietitians, psychologists, and social workers who offer education and counselling to patients and families.[39] Access to a health care team and the amount of time spent with diabetes care professionals (i.e., the total amount of time spent in face-to-face interactions during clinic) was found to be significantly correlated with HbA1c in children living with T1D ($R=0.269$; $p<0.0001$).[39] As this was a cross-sectional study, it is unclear whether time spent with professionals was a predictor or a result of HbA1c levels.

1.4 Health outcomes

1.4.1 Glycemic control

Glycemic control as measured by HbA1c reflects blood glucose levels for 3 to 4 months.[38] HbA1c measurements are often used for decision-making about medical regimens and are useful to assess the risk of long-term complications.

Glycemic targets are set for children with T1D to reduce the onset and progression of diabetes-related complications.[34] These targets are met through adherence to insulin regimens and glucose monitoring.[36] Treatment goals are determined by considering individual factors and guidelines and are set to ensure overall targets are met: children and adolescents under 18 years should aim for A1c $\leq 7.5\%$ as per the Diabetes Canada guidelines.[36] The guidelines also state that HbA1c targets should be individualized and set in consideration of access to technology, history of compliance to therapy, and history of hypo- or hyperglycemia unawareness.[38]

1.4.2 Acute complications: Diabetes-related Hospitalizations: DKA

DKA is a life-threatening complication caused by an insulin deficiency and characterized by hyperglycemia, ketosis and acidosis.[40] This complication most often occurs at diabetes onset in children; however, the rate of DKA occurring in those with established diabetes has increased in the past decade,[40] with a DKA risk of 1-10% per patient per year in Europe.[41,13]
In those with established T1D, the risk of DKA is increased in individuals with sub-optimal glycemic control and a history of previous DKA episodes.[41] Other situations that may lead to DKA include insulin pump delivery failure, insufficient insulin administration at times of increased insulin requirements such as intercurrent illness, or limited access to medical services, resulting in poor overall health outcomes.[18,13] High mean hospital admission rates related to DKA pose an economic burden for hospitals and families.[40] It is the leading cause of death in T1D children under 15 years, and the mortality risk from DKA increases with children who have sub-optimal glycemic control.[13,42] Mortality rates from DKA have decreased in the past decade. For example, between 1968 and 2009, DKA-related mortality in youth <19 years old decreased by 61% from 2.69 per million to 1.05 per million.[43] Potential reasons for the decrease in mortality rates include improved diabetes care and treatment, better awareness of symptoms, and advances in education concerning diabetes management.[13]

1.5 Factors that affect diabetes management

Adequate diabetes management depends on several factors mentioned, such as intensive insulin regimens, access to a diabetes care team, and appropriate screening for comorbidities. Moreover, several studies have identified that SES, demographic, and psychosocial factors affect diabetes management.[32,44,45]

1.5.1 SES and Processes of Care

Studies have demonstrated the role of adherence to medical appointments and access to care on HbA1c and risk of DKA.[44,46] One study examined the association between missed medical appointments and disease control, described as HbA1c at each follow-up visit and DKA

episodes during the 3.6 year study period, in children aged 0 to 18 years with T1D.[46] The study reviewed medical records of children receiving outpatient care for T1D at the Children's Hospital of Chicago. Results showed that patients with one missed appointment had more than twice the odds of having a DKA episode during the study period (Odds Ratio (OR) 2.50, 95% CI 1.32, 4.72), and almost twice the odds of having a mean HbA1c ≥ 8.5% (OR: 1.91, 95% CI 1.29, 2.80) compared to patients with no missed appointments. Patients with two or more missed appointments per year had three times the odds of having a DKA episode during the study period (OR: 3.20, 95% CI 1.70, 6.02), and three times the odds of having a mean HbA1c ≥ 8.5% during the study period (OR: 3.31, 95% CI 1.93, 5.67), compared to patients with no missed appointments.[46] Furthermore, the authors reported that ethnic minorities and children of low SES were overrepresented among those who are more likely to miss appointments. Among those who missed two or more appointments, Hispanic children represented 37.5% of the group and children with public insurance represented 64.8% of the group, whereas among those who missed no appointments per year, 16.0% were Hispanic and 22.7% had public insurance.[46]

Hershey et al. also reported that in children with T1D who are from low SES and racial and ethnic minority communities with poor glycemic control, the presence of at least one adverse social determinant of health and food insecurity was associated with having missed at least one appointment.[47] This may not be observed in every health care context. For example, a Canadian study by Zuijdwijk et al. of children with T1D found that the frequency of diabetes-clinic visits did not differ by deprivation quintile; patients from all quintiles had a median of 3 diabetes clinic visits per patient per year.[48] The authors hypothesized that this may have been due to the fact their clinic was easily accessible by public transport from urban and suburban areas.[48]

Clinical networks have been developed to foster continuity of care and equitable access to specialized diabetes services and mitigate the SES disparities in outcomes observed. For instance, after the implementation of the Network of Ontario Pediatric Diabetes Programs in 2001, there was a decreased trend in emergency department visits and hospital admissions which was seen across socioeconomic quintiles, as well as a decreased disparity in emergency visits and hospital admissions between children of the highest and lowest socioeconomic quintiles.[49] Nonetheless, although smaller, the association between lower SES and increased risk of emergency department visits and hospital admissions persisted.[49]

1.5.2 Psychosocial/Psychological factors and HbA1C

Psychosocial factors may also affect glycemic control through self-care behaviour. These include general and diabetes-specific stress, inadequate social support, poor coping skills, and stigma.[50,51] Psychological conditions such as depression, anxiety, and eating disorders have also been associated with worse glycemic control and lower adherence in adolescents living with T1D.[52,53] In a prospective observational study of 150 adolescents aged 13-18 years, a 14-point increase in anxiety scores, as measured by the State-Trait Anxiety Inventory for Children, was associated with a 1% increase in HbA1c ($p<0.05$) over a 12-month period.[52] Furthermore, the frequency of blood glucose monitoring over a 12-month period, an indication of adherence to the diabetes regimen, was reduced with increasing depression scores, as measured by the Children's Depression Inventory ($\beta= -0.05$, $p<0.05$). In a retrospective cohort study of adolescents aged 11-25 years with T1D, Bernstein et al. found that patients who had at least 1 positive mental health screen, defined as either depression, anxiety or disordered eating, had higher odds of having an HbA1c $\geq$ 8.5% (OR: 2.16, 95% CI 1.01, 4.65) compared to those who did not screen positive[53], suggesting that psychiatric comorbidities are an important consideration in the research and clinical setting, as children and adolescents living with T1D are at higher risk for psychological problems especially during mid-adolescence.[54] However, interpretation of the observations is limited given the cross-sectional design of this study, and further examination is needed to determine whether mental health issues lead to higher HbA1c levels.

Also, in a retrospective cohort study conducted in Quebec, Canada, using linked health administrative databases of adolescents (aged 15 years) with and without diabetes and followed to age 25 years, individuals with diabetes were more likely to suffer from a mood disorder (adjusted hazard ratio 1.33, 95% CI 1.19, 1.50), attempt suicide (3.25, 95% CI 1.79, 5.88), visit a psychiatrist (1.82, 95% CI 1.67, 1.98), and experience any type of psychiatric disorder (1.29, 95% CI 1.21, 1.37]) compared with their peers without diabetes.[54]

2 LITERATURE REVIEW

2.1 SES and diabetes outcomes

Studies in Europe and North America have highlighted inequalities in diabetes control, management, technology uptake and outcomes in various contexts with differing measures of SES such as insurance status, deprivation indices, and median household income.[55,56]

A retrospective multicenter population-based study using the SEARCH data examined the association between sociodemographic factors with glycemic control according to differing insulin regimens (i.e., insulin pumps, injections).[56] The cohort included children aged 10-17 years with incident T1D in 2001-2006 and 2008 who had a diabetes duration of at least 5 years. Public or private health insurance was included as a sociodemographic factor and glycemic control (i.e., HbA1c) was classified as either poor (≥9.5%), intermediate (7.5 to <9.5%), or good (<7.5%). A multivariate logistic model demonstrated that amongst those on insulin pump therapy, children with public insurance had twice the odds of having poor glycemic control compared to children with private insurance (OR 2.6, 95% CI 1.19, 3.38). This was adjusted for diabetes duration, ethnicity, sex, and age. The model was also adjusted for adherence which was evaluated by assessing diabetes-related family conflict (Diabetes Family Conflict Scale), hypoglycemia fear (Hypoglycemia Fear Survey), eating problems (Diabetes Eating Problem Survey), and frequency of blood glucose monitoring, as well as self-reported barriers-to-care. The latter included access barrier factors (e.g., lack of regular provider, cost of care) and process barrier factors (e.g., problems with receiving care and problems with not spending enough time with the provider). The study found that despite being on an insulin pump, lower SES was associated with poor glycemic control compared to those of higher SES.[56] Although subjective processes of care were described, an objective measure of processes of care such as the number of follow-up visits recorded in the past year was not evaluated.

A U.S. study by Majidi et al. found slightly different results in a cross-sectional analysis of children aged 12 to 19 years with T1D for at least 5 years, who presented for two study visits between 2008 and 2010.[57] Insurance status and parental education level were included as SES measures. Consistent with the SEARCH study described above, children with private insurance were more likely to have lower levels of HbA1c ($p<0.05$); however, this association was not statistically significant after controlling for insulin regimen ($p=0.1$). The authors suggested that public insurance coverage of insulin pump therapy in the institution where this study was

conducted led to better access to insulin pump therapy for individuals of low SES status and mitigated SES disparities.[57] Similarly to the SEARCH study, the present research did not investigate other factors that affect diabetes outcomes such as the frequency of clinic visits and routine care. Accounting for the frequency of clinic visits across insurance status may demonstrate underlying factors of disparities in glycemic control in children with T1D. Furthermore, the cross-sectional design of the study prevents it from capturing the full effect of factors contributing to glycemic control such as the use of insulin pumps overtime across insurance groups.

A study by Thompson et al. found similar results in a study focused on deprivation and its impact on insulin regimen and glycemic control in a cohort of children (aged < 19 years) with T1D living in London (UK).[32] Children who attended the institution's diabetes service in 2010 were included. HbA1c was measured at each quarterly visit and was averaged for the year. Deprivation score was determined from the postal code and included a measure of estimated household income, local environment, and household attainments. Access to care was conceptualized as the uptake of different insulin treatment modalities such as twice-daily injections, multiple daily injections, and insulin pump therapy. In a multiple linear regression analysis, only the mode of insulin therapy and ethnicity were associated with HbA1c. A sub-analysis was conducted within the White British group which had a sample size of 268. In the White British group, those on the twice-daily insulin therapy had a higher deprivation score, compared to those on multiple daily injections and those on insulin pump therapy ($p<000.1$). A one-way ANOVA comparison of the three insulin regimen groups revealed that those on insulin pump therapy had the lowest levels of HbA1c and those in the twice-daily group had the highest levels ($F=5.18$, $P=0.002$). Regression analysis also revealed that treatment regimen and ethnicity were the only significant variables associated with HbA1c; deprivation was not significant.[32]

Similarly, Apperley et al. focused on socioeconomic deprivation and trends of HbA1c in the UK in a retrospective cohort study of hospital admissions between 2007 and 2012.[58] Overall deprivation scores were measured by focusing on separate domains including income, employment, health and disability, education skills and training, barriers to housing and services, crime, and living environment. Analysis by Spearman's rank correlation found that poor

glycemic control was more likely in children living in the most deprived areas of the UK. Specifically, lower household levels of education and unemployment were significantly associated with poor glycemic control (r=0.22, p=0.02 (education); r=0.19, p=0.04 (unemployment)). The proportion of children using an insulin pump was only reported for 2011 (7%), 2012 (16%), and 2013 (33%); however, access to technology was not considered in the analysis of socioeconomic deprivation and glycemic control.

Research done by Delagrange et al. found differences in glycemic control by individual and area-level deprivation in France.[59] The multi-center cross-sectional study utilized the Evaluation of the Deprivation and Inequalities of Health in Healthcare Centers (EPICES), a validated deprivation index in France which measures individual deprivation based on employment, income, education level, socio-professional category, family composition, social connections, financial difficulties, life events, and perceived health. Area-level deprivation was measured by the European Deprivation Index (EDI). The sample included children who were diagnosed with T1D for at least a year and who attended hospital consultations from November 2017 to May 2018, in one of the seven pediatric health care centers in Occitanie, France. The main outcome was HbA1c and poor glycemic control was defined as HbA1c >8.5%. Linear regression models showed that poor glycemic control was associated with greater individual and area deprivation. Being in the most deprived EDI quintile was associated with a higher mean HbA1c (ß = 0.22, 95% CI 0.04, 0.40, P=0.017) in a fully adjusted model, including EPICES scores. An EPICES score greater than 30, indicating individual deprivation, was also associated with a higher mean HbA1c (ß =0.39, 95% CI 0.27, 0.52, P<0.001).[59] Descriptive analyses showed that the distribution of patients using an insulin pump was similar across individual and/or area deprivation levels. In addition, the authors described that patients with the highest individual deprivation score had a greater number of DKA events during the study period, compared to the least deprived group (P = 0.031).[59]

A Canadian study by Deladoëy et al. investigated the impact of median household income, as a measure for SES, on HbA1c in a pediatric population in Montreal.[60] The study population included children (aged <17 years) who were diagnosed with T1D at the study institution between 1980 and 2011. SES was measured by annual median household income by

neighbourhood-level data from the 2006 Canadian Census. The main outcome was mean HbA1c. A linear regression model showed a negative linear association with each $15 000 increase in income and metabolic control (ß =-0.1, P<0.001, r=-0.2). This model controlled for sex, age at diagnosis, duration of diabetes, ethnicity, frequency of visits, and time period (before vs. after February 2003). For the latter variable, HbA1c was measured with an immunological method before February 2003 and was measured with a high-performance liquid chromatography method after 2003. The difference in mean HbA1c between the highest and lowest median income was more than 1%, with a mean HbA1c of 7.20% (95% CI 6.75, 7.65%) in the highest, and 8.55% (95% CI 8.45, 8.65%) in the lowest. After adjusting the model to remove outliers (10 richest and 10 poorest households) this association remained significant (P<0.001). Although the study provided evidence for the effect of SES on diabetes outcomes in the context of universal financial coverage of health care, it only used one dimension of deprivation, median household income, without capturing other relevant dimensions of deprivation such as ethnicity.[60] Also, other important factors that may influence the impact of income, such as the use of insulin pumps or access to care were not considered in the study.

Another Canadian study examining social determinants of health and HbA1c found significant associations between deprivation index scores and HbA1c in patients with T1D followed at the Hospital for Sick Children in Toronto, Ontario from 2010 to 2011.[48] Social determinants of health were measured using the Material and Social Deprivation Index (MSDI) from the *Institut national de santé Publique du Quebec* (INSPQ), as well as the Ontario Marginalization Index (ON-Marg) which determines ethnic concentration. The main outcome was mean HbA1c during the study period. The effects of the number of diabetes clinic visits per year, age, sex, and pump status on the associations were also assessed. Two-sample t-tests were used to compare the difference in HbA1c levels between the least and most deprived quintiles. Results showed higher HbA1c levels in patients with the greatest degree of deprivation on the Material DI (HbA1c difference 0.9, P<0.0001), the Social DI (0.7, P<0.0001), and the Ethnic Concentration Index (0.5, P=0.04), when adjusting for age and sex, compared to those who are least deprived. Stratification of patients according to insulin pump use showed significantly higher HbA1c levels in patients with the greatest degree of deprivation on the Material DI (P<0.0001) and the Social DI (P=0.003), compared to those who are least deprived among those

not using an insulin pump. On the contrary, no significant difference in HbA1c was found between the least and most deprived groups among patients using an insulin pump, suggesting that insulin pump status had a modifying effect on the association. Furthermore, multivariate linear regression showed that variables that were significantly associated with higher HbA1c included being in the most deprived quintile (ß =1.77, P<.0001), off insulin pump (B=0.69, P<0.0001), age (ß =0.03, P=0.01), and female (ß =0.26, P=0.01). In addition, the number of diabetes-clinic visits did not differ by deprivation quintile; therefore the authors concluded that patients in this study population had equal access to health care, as measured by diabetes clinic visits, and that differences in glycemic control may be due to mediating factors that were not measured, such as access to additional diabetes care outside of clinic time, differences in literacy and numeracy, perception of health, or use of insulin pump.[48]

2.2 Race, ethnicity, and diabetes outcomes

Peer-reviewed studies have been published about ethnicity, race, and diabetes outcomes in children with T1D, mainly outside of Canada.[32,55,56] Notable disparities in HbA1c and the occurrence of DKA by ethnicity have been reported. Some of these findings originate from the aforementioned studies (section 2.1) on SES and diabetes outcomes.[17,32,55,56]

Research by Snyder et al. found that minority race/ethnicity (non-Hispanic white) was associated with higher HbA1c.[56] The SEARCH study also examined ethnic differences in glycemic control within each insulin regimen. Insulin regimens were classified as either 1) insulin pump therapy, 2) basal-bolus injections, and 3) a mixed insulin regimen, which included multiple daily injections (≥ 3 injections) of basal insulin, intermediate-acting, or rapid-acting insulin, multiple daily injections (≥ 3 injections) with any insulin types excluding basal insulin, and multiple daily injections (1-2 injections) excluding basal insulin. Poor glycemic control was defined as HbA1c ≥ 9.5% as per ADA guidelines. Non-White race was associated with higher odds of poor glycemic control in an unadjusted logistic regression model (OR 2.7, 95% CI 1.74, 4.12) including all three insulin regimens. In an adjusted logistic regression model which accounted for clinical, sociodemographic, adherence, and barriers-to-care factors, Non-White race remained significantly associated with poor HbA1c (OR 2.7, 95% CI 1.5, 4.72) only in

patients using an insulin pump. Although insulin pump users had the best glycemic control, ethnicity was a significant predictor of poor glycemic control in this group, when other factors were controlled for such as barriers-to-care (lack of a regular provider, cost of care), adherence (diabetes-related family conflict, hypoglycemia fear, eating problems, and frequency of blood glucose monitoring) and sociodemographic factors.

Khanokolar et al. found significant results for the impact of ethnicity on HbA1c in a large cohort of children (<19 years) with T1D in England and Wales where the National Health Service provides free health care, covering the costs of T1D treatment.[55] Ethnicity was self-reported according to the following categories: White, Asian, Black, mixed, other and 'not stated'. The main outcome was mean HbA1c levels. Compared to the White ethnic group, all other ethnicities had higher mean HbA1c levels with the highest levels observed in the Black (9.5%, $p<0.0001$) and mixed ethnicity (9.4%, $p=0.0001$) groups.[55] Low SES was associated with higher HbA1c across all ethnic groups; however, adjusting for SES and insulin pump use showed a smaller effect for Asian children but not for Black and mixed children. This suggests that for Asian children, HbA1c were likely affected by the lack of access to insulin pumps in addition to cultural beliefs, lifestyle and health care access which may likely affect Black and mixed children in the sample.[55]

Another study by Khankolar et al. further examined ethnic differences in the stabilization of HbA1c in the first six months postdiagnosis, its effect on subsequent HbA1c, and the severity of DKA at diagnosis in a longitudinal cohort study of newly diagnosed patients aged <19 years with T1D from three different diabetes clinics in East London, UK.[61] Primary exposure was self-reported ethnicity using 15 ethnic categories collapsed into 6 groups including White, Mixed ethnicity, Black, African-Somali, Bangladeshi and Asian-Other. These ethnic groups reflected the ethnic distribution of the study area. Results showed that ethnic minority groups presented with higher mean HbA1c at diagnosis compared to White children, and this difference was only statistically significant in the Bangladeshi and South Asian groups (3.0%, 95% CI 2.5, 3.4; 2.7%, 95% CI 2.4, 3.0, respectively), and in the Somali-group only after adjustment by SES (2.6%, 95% CI 2.2, 3.1). These groups also had the highest mean difference in HbA1c levels at diagnosis compared to White children.[61] Although the type of insulin regimen was not available

in the sample, the authors state that only a small proportion was on insulin pump therapy. Ethnic differences persisted after controlling for SES which indicates that there are important drivers of these disparities that should be examined beyond SES.

Thompson et al. also found disparities in HbA1c and access to care by ethnicity in a study conducted in the UK.[32] Ethnicity was self-reported using the National Health Service Standard Demographic data set and was grouped as White British, African, Asian non-Indian, or Asian Indian. Analysis by ANOVA demonstrated that HbA1c levels were highest in the African group and lowest in the British White group ($P<0.001$). Furthermore, in a multivariate model adjusted for deprivation score, gender, age, and treatment regimen, ethnicity and insulin pump therapy were associated with HbA1c (ANOVA with the Tukey honestly significant difference post hoc test; ethnicity $t=4.18$, $p<0.001$; insulin pump $t=2.79$, $p=0.005$). White British and Indian Asian groups were more likely to receive insulin pump therapy ($\chi^2= 50.3$, $p <0.001$).[32] The observation that ethnicity was a strong correlate for higher HbA1c, despite high attendance rates across all ethnic groups, suggested that additional factors may have contributed to these differences, although insulin pump use was a major factor being associated with lower HbA1c in a one-way ANOVA ($F=7.02$, $p\leq0.001$) and more likely to be used by the White British and Asian Indian groups. Language barriers may impede the communication between health care providers and some ethnic groups. Also, the way different health care professionals approach different ethnic groups and understand different lifestyles and views on health care (i.e. lack of culturally safe care from health care providers) can influence these disparities.[32]

Lipman et al. conducted a retrospective chart review of children (<18 years) with T1D from the Diabetes Center at Children's Hospital of Philadelphia between October 2018 and December 2019.[62] Electronic health records were reviewed to investigate the effects of either government or commercial insurance, as a proxy for SES and race/ethnicity on diabetes outcomes, including HbA1c. Ethnic categories included Non-Hispanic White, Non-Hispanic Black, and Hispanic, which largely represented the ethnic diversity of Philadelphia. Non-Hispanic White children had significantly lower HbA1c levels (7.8%) compared to Non-Hispanic Black children (8.6%; $p<0.001$) in commercially and government-insured patients. In logistic regression analysis adjusted for age and diabetes duration, Non-Hispanic Black children

had higher odds of having suboptimal glycemic control, defined by HbA1c ≥ 7.5% (OR: 4.9, 95% CI 3.1, 7.7) compared to Non-Hispanic White children which was also observed within the commercially insured group; Non-Hispanic Black children had higher odds of poor glycemic control compared to Non-Hispanic White children (OR: 5.1, 95% CI 2.6, 10.1). The authors were able to distinguish the effect of SES from race/ethnicity on diabetes outcomes in this sample and concluded that while SES was an important factor, cultural factors and implicit racial/ethnic bias may also contribute to disparities observed within the commercially insured group.[62]

Willi et al. examined racial/ethnic disparities in children with T1D using data from the T1D Exchange Clinic Network which includes 73 pediatric and adult endocrinology practices in the U.S. with data collected from medical records since September 2010.[63] The retrospective cohort study included children (ages <18) from 60 pediatric sites who were enrolled in the registry between August 2010 to August 2012, with T1D for at least a year, who identified as either White, Black, or Hispanic which were the race/ethnicity categories included in the study.[63] Demographic information was obtained through questionnaires completed by parents/guardians of patients or patients including frequency of blood glucose monitoring, DKA events, severe hypoglycemic events, and SES. SES was defined by household income, highest parental education level, and insurance status – either private, nonprivate, or no insurance. Insulin regimen was obtained for each participant based on medical records and HbA1c measurements from 6 months before and 1 month after enrollment were collected. Linear mixed model adjusted for age, gender, BMI z-score, diabetes duration, pediatric site effect, and SES showed significant differences in mean HbA1c between Black and White children ($p < 0.001$) and between Hispanic and Black children ($p < 0.001$); no significant difference in mean HbA1c was found between Hispanic and White children. Among children using a pump, mean HbA1c was significantly lower across all racial/ethnic groups with the greatest difference among Black children which indicated a significant interaction between race/ethnicity and insulin regimen ($p<0.001$). Nonetheless, Black children had the lowest percentage of pump use compared to White children after adjusting for SES in binary mixed models also adjusted for age group (1 to 6 years, 7 to 13 years, 14 to 18 years), gender, diabetes duration, interaction between age group and diabetes duration ($p<0.001$). Although this study includes a racially/ethnically diverse sample of children, the investigation of White, Black, and Hispanic groups may have excluded other minorities in

the population, therefore the findings may not be generalizable to populations with a more complex racial and ethnic composition.

3 RATIONALE AND RESEARCH OBJECTIVES

SES disparities in processes of care and health outcomes have been reported in children with T1D. Specifically, two U.S. studies found that insurance status, a common measure of SES, was a predictor for glycemic control.[56,57] Likewise, two studies in the UK reported that area deprivation was associated with glycemic control.[32,58] A study in France found similar results where individual and area deprivation predicted glycemic control in children with T1D.[59] Two Canadian studies have described socioeconomic disparities in glycemic control.[48,60] Higher HbA1c levels were highest in patients with the greatest degree of Material and Social deprivation.[48] These Canadian studies used data prior to 2012 and 2013, since then, newer technologies and access to technologies have changed.

The literature also demonstrates evidence of ethnic disparities. U.S. studies have consistently reported that children of Non-White race are more likely to have poor glycemic control.[56,62] Three studies in the UK also found that compared to White children, Black and South Asian children had higher HbA1c levels.[32,55,61] There has been growing evidence of health inequalities in racialized groups in Canada including ethnic minorities.[64] However, evidence of ethnic disparities in diabetes outcomes in children with T1D in Canada is limited, and other equity measures that affect diabetes outcomes such as immigration status have not yet been addressed in a Canadian context.

Factors beyond individual characteristics and diabetes care should be addressed to understand social inequities that contribute to diabetes outcomes. Lipman and Hawkes proposed a conceptual framework that describes the standard approach to care for T1D which is mostly centered on individual characteristics and aspects of diabetes care, with less focus on the impact of social determinants, society, and public policy.[65] The model suggests that other factors, including SES, structural racism, federal programs and health insurance can contribute as barriers to diabetes care and should be considered to address health disparities.[65]

Although some of the literature addresses pathways by which SES impacts glycemic control, few studies have examined ways that social factors interact with components of diabetes care and individual factors that can be addressed to help reduce disparities. For example, only one Canadian study examined whether insulin pump use modified the effect of low SES on glycemic control.[48] Also, studies have addressed that attendance to medical appointments contributes to optimal glycemic control[46], however, no study has examined whether these processes of care interact with SES to affect glycemic control. Furthermore, little is known about how psychosocial factors interact with SES to impact glycemic control. A Canadian study on an adult population with T2D in Montreal found that glycemic control of individuals of low SES can be maintained by targeting factors that mediate the relationship between SES and glycemic control such as depression, coping strategies for stress, and management of diabetes such as a healthy diet.[50] There is an opportunity to highlight socioeconomic and racial disparities in the Canadian pediatric population living with T1D and identify factors that can mitigate them.

The objectives of this research were to examine socioeconomic disparities in diabetes outcomes among children in Montreal, Quebec. The objectives sought specifically to determine the relationship between health equity measures and glycemic control. The main analysis and conceptual model for the research are shown in Figure 1. The effect of SES on children's HbA1c levels has been established in the literature. The Material and Social Deprivation Index (MSDI) from the INSPQ measures socioeconomic characteristics on two dimensions, material, and social deprivation, based on six indicators that relate to health, material wealth, or social connectedness which include: proportion of people without a high school diploma, employment to population ratio, average income, the proportion of individuals living alone, the proportion of people separated, divorced, or widowed, the proportion of single-parent households. Given the relationship of these variables with health outcomes, we hypothesized that compared to higher SES, lower SES as measured with the MSDI was associated with worse glycemic control, as measured by mean HbA1c.

The secondary objective was to examine whether other variables have a modifying effect on the relationship between SES and glycemic control, such as insulin pump use, processes of

care, and depressive symptoms, as shown in Figure 2. The use of insulin pumps is beneficial for glycemic control and programs in Quebec have made insulin pump therapy more accessible to individuals of lower SES. With such programs, we hypothesized that the use of insulin pumps would have a modifying effect on the association between SES and glycemic control (i.e., no significant association between SES and glycemic control among those using an insulin pump). . The recommended processes of care for children with T1D include at least three diabetes-related physician visits in a year for optimal diabetes care and management. We hypothesized that adherence to these guidelines would also have a modifying effect on the relationship between SES and diabetes health outcomes with no association between SES and glycemic control for those with optimal adherence. Furthermore, depressive symptoms in children with T1D are common and affect glycemic control through less monitoring and less self-care behaviour.[51] We hypothesized that depressive symptoms would also have a modifying effect on the relationship between SES and glycemic control in children with T1D; where there would be no significant association between SES and glycemic control for those with a positive depression screen. Additionally, the effect of race, ethnicity and immigration status on health outcomes have been described. Inequalities related to race and ethnicity are often a result of a lack of access to care, language and cultural barriers which prevent individuals from adhering to and receiving optimal care. As part of the secondary objective, we will also examine the relationship between ethnicity, immigration, and glycemic control in a subgroup, as depicted in Figure 3.

Summary of Research Objectives

The primary objective was to determine the association between SES and mean HbA1c in children and adolescents aged 0 to 18 years with T1D followed at the Montreal Children's Hospital between November 1st, 2019 and October 31st, 2020, adjusting for age, sex, and diabetes duration, insulin pump use, and processes of care.

The secondary objectives were:

1) To assess whether processes of care (as measured by the number of diabetes-related physician visits over a year), insulin pump use, and depression modifies the association between SES and mean HbA1c.

2) Determine the association between a) ethnicity and b) immigration status and mean HbA1c adjusting for age, sex, diabetes duration, SES, insulin pump use, and processes of care.

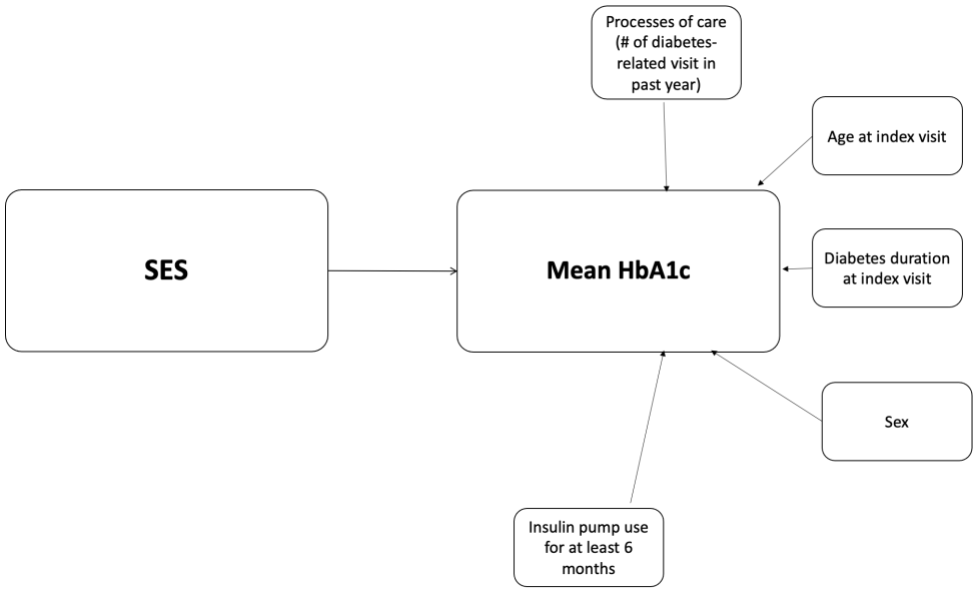

Figure 1. Association between SES and mean HbA1c

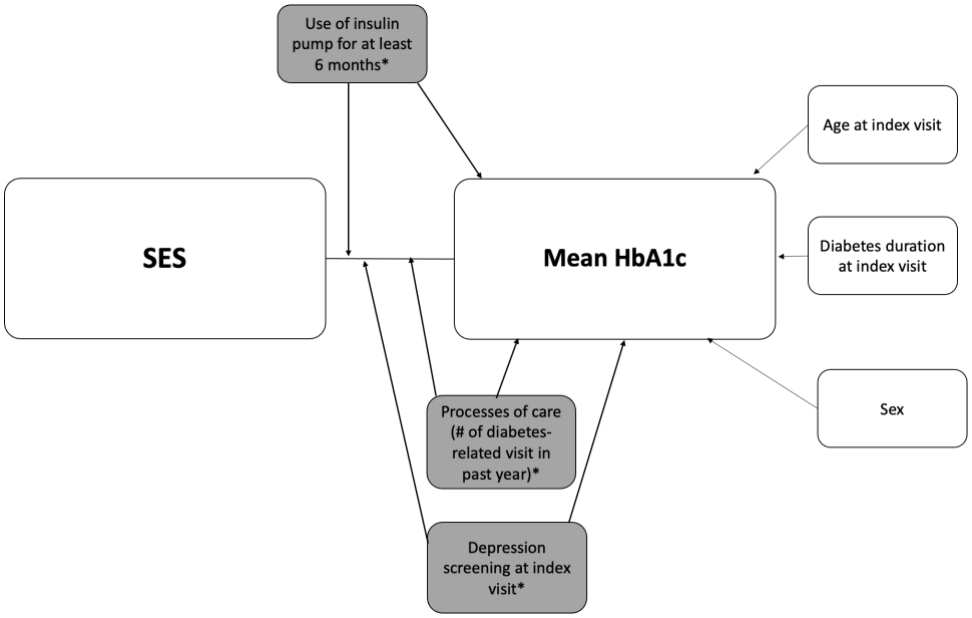

Figure 2. Effect modification of insulin pump use, processes of care and depression on the association of SES with mean HbA1c

*Effect modification by the covariate

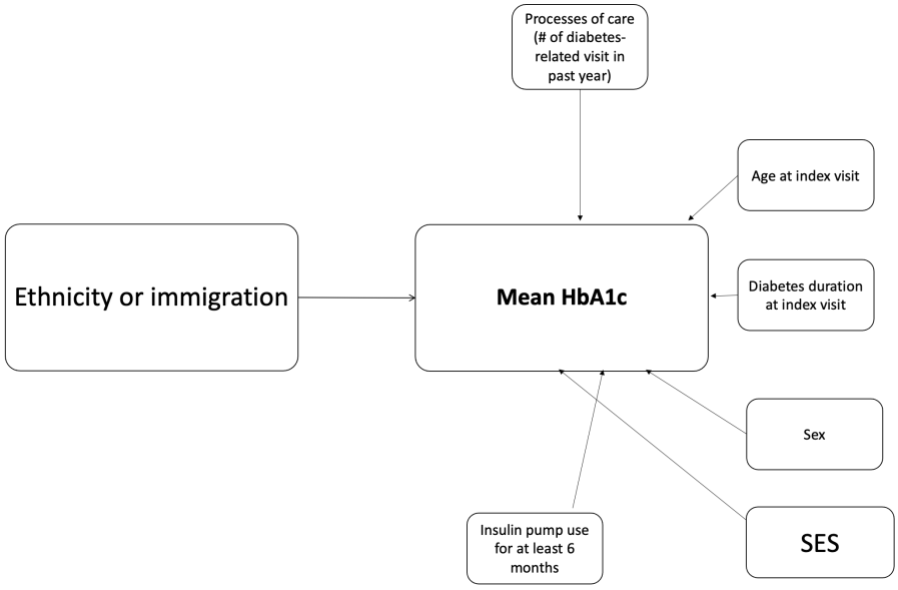

Figure 3. Association of Ethnicity/immigration and mean HbA1c

4 Health disparities in children with Type 1 diabetes

4.1 Abstract

Objectives

The primary objective was to determine the association between socioeconomic status (SES) and glycemic control, as measured by mean hemoglobin A1c (HbA1c), in children and adolescents aged 0 to 18 years with type 1 diabetes (T1D) followed at the Montreal Children's Hospital (MCH) for their diabetes care. The secondary objectives were to 1) determine whether insulin pump use, processes of care (determined by the number of diabetes-related physician visits in the past year), and depression were effect modifiers of this relationship, and to 2) determine the association between a) ethnicity and b) immigration status and mean HbA1c.

Methods

A retrospective cohort study was conducted on children aged 0 to 18 years diagnosed with T1D for at least a year who had an index visit for diabetes care at the MCH between November 1st, 2019, and October 31st, 2020. SES was measured with the Material and Social Deprivation Index (MSDI) from the Institut National de Santé du Québec (INSPQ), based on the 2016 Canadian Census. Ethnicity, immigration status, and depression were self-reported and measured for a subgroup. The main outcome was mean HbA1c measured during the one year after the index visit. Multivariable linear regression was used to examine associations between SES, ethnicity, and immigration with mean HbA1c. Multivariable linear regression with interaction terms was used to examine effect modification of SES and mean HbA1c by insulin pump use, processes of care, and depression.

Results

Of the 208 children meeting inclusion criteria for the cohort, the MDSI quintile was assigned to 203, of which 47.8% were in the least deprived quintiles (Q1 and Q2), 26.6% were in the moderately deprived quintile (Q3), and 25.6% were in the most deprived quintiles (Q4 and Q5). In the multivariable linear regression analyses, children in the most deprived quintiles had a higher mean HbA1c (β=0.50, 95% CI 0.04, 0.97). Effect modification by insulin pump use, processes of care, and depression were not significant.

In a subgroup of 183 children with ethnicity data, 68.9% identified as White, 11.5% as Middle Eastern, 3.3% as Black and 8.7% were classified as "Other" and included East/Southeast Asian, Indigenous, Latino, South Asian, and other unspecified. In the adjusted analysis, children from racialized groups had a mean HbA1c 0.64% higher than children from non-racialized groups (β=0.64, 95% CI 0.15, 1.13). Immigration status was not associated with mean HbA1c.

Conclusions

The observed associations between socioeconomic status, ethnicity, and glycemic control are important for further research to understand drivers that contribute to these disparities in a Canadian context.

4.2 Introduction

Social determinants of health influence diabetes management through access to health care and technology, and disease management.[47,65] Studies of children and adolescents with T1D have demonstrated that social and ethnic disparities have an impact on diabetes health outcomes.[32,48,66] The impact of socioeconomic status (SES) has been examined as measured by insurance coverage, household income, parental education, poverty rate, and deprivation indices.[17,44] Studies have reported that SES is associated with diabetes health outcomes through access to treatments,[32] adherence to guidelines and health care utilization,[67] and access to additional diabetes care,[48] and that children of low SES are at a greater risk of having a higher hemoglobin A1c (HbA1c) compared to children of high SES.[47,48,56,57,59,60] Few studies investigated this question while considering the Canadian context, which offers universal financial coverage for health care. Furthermore, little is known about factors that may modify the relationship between SES and glycemic control, such as mental health factors, health care utilization, adherence to diabetes guidelines, and access to insulin pumps. The current study aimed to 1) determine the association between SES measured by the Material and Social Deprivation Index (MSDI) and mean HbA1c, where SES was also measured by the Canadian Index of Multiple Deprivation (CIMD); 2) determine whether this association was modified by insulin pump use, processes of care (determined by the number of diabetes-related physician visits in the past year), and depression; and 3) determine the association between a) ethnicity and b) immigration status and mean HbA1c.

4.3 Methodology

4.3.1 Study design

This was a retrospective cohort study.

4.3.2 Population and setting

We included children aged 0 to 18 years who had T1D for ≥1 year and an index diabetes-related physician visit at the MCH between November 1st, 2019, and October 31st, 2020. Children are typically seen at the MCH diabetes clinic 3 times a year which includes physician visits.
The index date was defined as the date with the first diabetes-related physician visit recorded between November 1st, 2019, and October 21st, 2020. Diagnosis of T1D was based on Clinical practice Guidelines (CPG) for diabetes.[68] Children with type 2 diabetes, pre-diabetes, other specific types, and gestational diabetes were excluded. Children who were diagnosed for at least a year but did not have previous visits recorded in the database as they had been receiving care elsewhere were excluded. Children with no HbA1c measures were excluded from the analysis due to missing values for the main outcome.

4.3.3 Data collection

We used data from the Montreal Children's Hospital Pediatric Diabetes Database, a REDcap database, which contains patient-level and visit-level data abstracted from medical records for children with T1D seen at the MCH from 2017 to date. Demographic information collected at the index visit included: sex, age, and postal code. Additional patient information included date of diagnosis, diabetes type, date of follow-up visits, HbA1c, and insulin pump use. The Diabetes Clinical Intake Form database, which includes data from caregiver- and/or youth- administered questionnaires, was used to collect other demographic information in a subgroup of patients including self-reported ethnicity and immigration status. The database also included depression screening by the Patient Health Questionnaire (PHQ-2) score, a two-item depression screening

tool. Variables collected at each visit and used for analyses included: HbA1c and insulin pump use.

4.3.4 Variables

Baseline demographics

Age at the index visit was calculated by subtracting the date of birth from the date of index visit. Sex was reported in the database as either male or female. Duration of diabetes was determined by subtracting the date of diagnosis from the date of the index visit.

Primary exposure: SES

The primary SES variable was determined with the MSDI quintiles, which is assigned using the child's postal code at the index date. The validated deprivation index is based on socioeconomic indicators drawn from the 2016 Canadian Census at the dissemination area level, which are small area units of 400 to 700 persons. The socioeconomic indicators include the proportion of single-parent families, the population aged 15 years old and over, the proportion without a high school diploma or equivalent, the employment to population ratio, the average income, the proportion living alone, and the proportion who are separated, divorced, or widowed.[68]

Postal codes at index date were linked to the MSDI datasets provided by the *Institut National de santé Publique du Québec (*INSPQ) to determine deprivation quintiles. There are four MSDI versions for Canada: a national version, regional version, metropolitan version, and a version for geographical zones.[69] For this study, the regional index for Quebec was used. The postal codes were linked to the MSDI files using SAS EG 9.4. The resulting dataset contained each postal code and the corresponding deprivation quintile. An overall combined deprivation quintile was determined by grouping the social deprivation and material deprivation quintiles assigned based on the methodology recommended by INSPQ.[69] We grouped the least deprived quintiles, 1 and 2, and the most deprived quintiles 4 and 5. This resulted in 3 groups: Q1 and Q2 (least deprived), Q3 (moderately deprived), and Q4 and Q5 (most deprived).[70]

The MSDI is a validated and most widely used tool to measure deprivation in Canada. In a sensitivity analysis, we also measured SES with the Canadian Index of Multiple Deprivation (CIMD), another validated tool to measure deprivation in Canada, which provides a comprehensive measure of deprivation using additional constructs compared to the MSDI.[71] Thus adding the CIMD as measure of SES would provide additional information on aspects of deprivation that are associated with health outcomes that may not be addressed with the MSDI. The CIMD is based on the 2016 Canadian Census and is generated by linking postal codes to data from dissemination areas. For this study, the regional index for Quebec was used. The index contains four dimensions: residential instability, economic dependency, ethnocultural composition, and situational vulnerability (Table 1). Each dimension was considered separately as they each measure a specific aspect of deprivation.

Table 1. The four dimensions of multiple deprivation and their corresponding indicators for Quebec in the CIMD, 2016[72]

*The indicators are reversed-coded

Residential Instability	Ethnocultural Composition	Economic Dependency	Situational Vulnerability
• **Proportion of persons living alone** • **Average number of persons per dwelling** • **Proportion of population that is married or common-law*** • **Proportion of dwellings that are owned*** • **Proportion of dwellings that are apartment buildings** • **Proportion of the population who moved within the past five years** • **Proportion of population that is low-income**	• Proportion of population that is foreign-born • Proportion of population who self-identify as visible minority • Proportion of population with no knowledge of either official language (linguistic isolation) • Proportion of population who are recent immigrants (arrived in five years prior to Census)	• Proportion of population aged 65 and older • Proportion of population participating in labour force (aged 15 and older)* • Ratio of employment to population* • Dependency ratio (population aged 0-14 and aged 65 and older divided by population aged 15-64)	• Proportion of population that identifies as Aboriginal • Proportion of dwellings needing major repairs • Proportion of population aged 25-64 without a high school diploma

Deprivation quintiles for each dimension were obtained by linking postal codes to the Postal Code Conversion File (PCCF), which assigns each postal code to a DA. The resulting dataset was then linked to the Quebec provincial index to assign quintiles within each dimension of the index, with 1 being the least deprived and 5 being the most deprived. We grouped the least deprived quintiles, 1 and 2, and the most deprived quintiles 4 and 5. This resulted in 3 groups: Q1 and Q2 (least deprived), Q3 (moderately deprived), and Q4 and Q5 (most deprived).

Insulin pump use

Insulin pump status was recorded at each visit. Children were considered on the pump if they had been on an insulin pump for at least 6 months by their index visit and during all study period visits afterwards. For instance, children who were on the pump for 3 out of 4 visits were not considered being on the pump. The number of visits during the study period was determined for each patient, as well as the proportion of visits where the insulin pump status was either on-pump or off-pump

Processes of care

Processes of care were measured by the number of diabetes-related physician visits in the year before the index visit. A variable was created to categorize patients who had less than three, three to four, and more than four visits in the past year according to a definition of optimal adherence derived from pediatric endocrinologists across Canada.[37] Processes of care was categorized into three groups to account for a possible non-linear relationship between HbA1c and numbers of diabetes-related physician visits.[67]

Outcomes

The primary outcome was mean HbA1c in the year following the index visit. At the MCH, HbA1c is measured with a capillary blood sample using point of care testing using the DCA Vantage analyzer. The reagent kit uses 1 uL of whole blood and a reading is obtained through an optical window (Bayer Vantage Hemoglobin A1c Reagent Kit). HbA1c was measured and recorded at each visit as a percentage. A minimum of one HbA1c measurement was required for

inclusion in the study; each patient's HbA1c measure was averaged and included for the analysis.

Variables for the subgroup analysis

The Diabetes Clinical Intake Form contains long and short format forms that collect demographic and clinical information of patients such as self-reported ethnicity, the patient's and caregiver/parent's immigration status, and scores of the PHQ-2 (a two-item depression screening tool). Information from this database was used to conduct a subgroup analysis, to determine the association between ethnicity and immigration status with diabetes outcomes, and depression as an interaction term in the main model.

Depression

Information on depression screening for the child was available from the PHQ-2, which contains the following questions: "During the past two weeks, I/my child has had little interest or pleasure in doing things" and "during the past two weeks, I/my child has felt down, depressed, or hopeless". The PHQ-2 is a screening instrument for depression which is comprised of the two first items of the full screening instrument (PHQ-9). Scores for the PHQ-2 range from 0-6; a score of 3 or greater signifies a positive depression screen.[73]

Ethnicity

Self-reported ethnicity was available in the database as a categorical variable for the following ethnic groups: Arab, Black, Chinese, Filipino, First Nations, Inuit, Japanese, Korean, Latin American, Métis, South Asian, Southeast Asian, West Asian, White, Other, Unknown, Prefer not to answer.[74]

Ethnicity was collapsed into 8 mutually exclusive groups, based on proposed groupings by the Canadian Institute for Health Information:[75] Black, East/Southeast Asian, Indigenous, Latino, Middle Eastern, South Asian, White, Other, Unknown, prefer not to answer. The groups were categorized as either racialized or non-racialized according to Statistic Canada's definition of visible minority.[76] The term racialized is used as defined by the Ontario Human Rights Commission.[77]

Immigration status

Self-reported immigration status was defined as either 1) at least one parent/caregiver and child are both non-immigrants, 2) both parents/caregiver and child are both immigrants, 3) at least one parent is an immigrant and child is a non-immigrant.

4.3.5 Statistical Analysis

Descriptive statistics were computed for patient characteristics, including mean and standard deviation (SD) for continuous variables, and proportions for categorical variables. Analysis of variance (ANOVA) was used for comparison of continuous variables between the SES categories, including age, diabetes duration, HbA1c, and the number of physician visits in the past year. Chi-square tests were used for comparison of categorical variables between the SES categories: sex, insulin pump use, physician visits, and HbA1c less than/above 7.5%. HbA1c of 7.5% was chosen based on the Diabetes Canada Guideline's target HbA1c for individuals aged < 18 years.[36] Mean HbA1c were also compared between patients on and off-pump therapy and physician visits (<3, 3-4, >4) by ANOVA.

To determine the association between SES and mean HbA1c, a multivariable linear regression model was conducted with SES as the primary exposure and mean HbA1c as the primary outcome. Age, sex, diabetes duration, insulin pump use, processes of care, were included as covariates and determined *a priori*.

A multivariable linear regression analysis was conducted to determine the association between SES and HbA1c, with an interaction term for insulin pump therapy to assess for effect modification of SES by insulin pump status. Covariates included age, sex, diabetes duration, and processes of care.

To assess effect modification of SES group by processes of care on mean HbA1c, the interaction between SES and diabetes-related physician visits (<3, 3-4, >4) was included in a multivariable linear regression model with age, sex, duration of diabetes, and insulin pump use as covariates.

4.3.6 Subgroup analysis

Analyses were conducted on the subgroup with information on self-reported ethnicity, immigration status and depression. In a descriptive analysis, we compared ethnicity, immigration status and depression by SES categories using Chi-square tests

We repeated the multivariable linear regression model described in the main analyses to determine the association of SES with HbA1c and included an interaction term for depression to assess for effect modification by depression. As before, the model adjusted for age, sex, duration of diabetes, insulin pump use, and processes of care.

The effect of ethnicity, categorized as racialized vs. non-racialized, on mean HbA1c was determined by multivariable linear regression analysis adjusted for SES (measured by the MSDI), age, sex, diabetes duration, insulin pump use, and processes of care. Similarly, the association between immigration status and mean HbA1c was determined by multivariable linear regression with the covariates SES, age, sex, diabetes duration, insulin pump use, and processes of care.

Sensitivity analysis
A sensitivity analysis was conducted to measure SES with the Canadian Index of Multiple Deprivation (CIMD). The association between deprivation measured by each dimension of the CIMD and mean HbA1c was determined by a multivariable linear regression model, adjusted for age, sex, diabetes duration, insulin pump use, and processes of care.

A sensitivity analysis was also conducted wherein those on insulin pump therapy for at least half of the visits during the study period were also considered to be on insulin pump therapy. This was done to determine if there were any differences in the association by including those who were on the pump for at least 50% of the follow up visits.

Sample size

To detect a minimal clinically important difference in mean HbA1c of 0.5[48,78] between the least deprived and most deprived groups with a desired power of 0.8, we estimated that a minimum of 64 individuals in each group was needed, assuming a common standard deviation of 1% using a two group t-test with a 5% two-sided significance level. Given that there were 3 SES groups, a total of 192 individuals was required.

Assignment of MSDI quintiles was done using SAS version 9, and all analyses were performed with R Studio. The statistical tests were 2-sided with significance at $p < 0.05$. Ethics approval was obtained from the Research Ethics Board of the Research Institute of the McGill University Health Centre.

4.4 Results

STUDY POPULATION

Diabetes database

As of January 2nd, 2022, there was a total of 266 patients recorded in the database. Ten patients were excluded for non-T1D. We excluded 40 patients (15%) who had not been diagnosed with T1D for at least one year. We excluded 7 children for having no HbA1c measurements.

MSDI quintiles

After linking with the MSDI datasets to assign deprivation quintiles, 4 patients were excluded as they matched to a dissemination area with no deprivation index and were assigned a missing value. Two were excluded for having a postal code that was not part of the PCCF and was assigned an index value of zero. The characteristics of excluded subjects are presented in Appendix 1. A total of 203 patients were included in the analysis using the MSDI quintiles to measure SES.

Diabetes clinical intake form

Approximately 345 patients completed the Diabetes Clinical Intake Form, which included 203 children from the main database. From the 203, a total of 183 were included for the analysis involving ethnicity, after 20 were excluded (10%) for the following reasons: 13 preferred not to report ethnicity and 7 had missing values. From the 203, a total of 192 were included for the analysis involving depression screening scores 11 (5%) children were excluded for missing scores. A total of 113 patients had information on the parent/caregiver or child's immigration status, after 90 children were excluded from the 203 for missing information on immigration status. A flowchart is presented in Appendix 2.

Table 2. Population Characteristics across MSDI quintiles

	Total	**Q1+Q2**	**Q3**	**Q4+Q5**	**p-value**
	N = 203 (100%)	**N=96 (47.3%)**	**N=54 (26.6%)**	**N=53 (26.1%)**	
Age (years), *mean (SD)*	13.5(3.5)	13.9 (3.1)	13.3(3.8)	12.8 (3.9)	0.12
Sex (male), *n (%)*	108 (53.2)	47 (49.0)	32 (42.6)	29 (54.7)	0.46
Duration of diabetes (years), *mean (SD)*	4.9 (3.8)	5.1 (3.9)	4.4 (3.5)	5.0 (4.0)	0.49
Insulin pump (yes), *n (%)*	76 (37.4)	39 (40.6)	23 (42.6)	14 (26.4)	0.15
# of MD clinic visits over the past 12 months, *mean (SD)*	3.4 (0.9)	3.4 (1.0)	3.5 (0.8)	3.5 (0.9)	0.45
# MD visits, *n (%)*					0.78
< 3 visits, *n (%)*	23 (11.3)	13 (13.5)	4 (7.4)	6 (11.3)	
3-4 visits, *n (%)*	165 (81.3)	75 (77.3)	47 (87.0)	43 (81.1)	
> 4 visits, *n (%)*	15 (7.4)	8 (8.3)	3 (5.6)	4 (7.5)	
HbA1c %, *mean (SD)*	8.3 (1.4)	8.2 (1.3)	8.2 (1.3)	8.7 (1.5)	**0.05**
HbA1c ≤ 7.5%, *n (%)*	60 (29.6)	33 (34.4)	14 (25.9)	13 (24.5)	0.33

The population characteristics of the main database are shown in Table 1. The mean (SD) age at index visit was 13.5 (3.5) years and 53.2% were male. The mean duration of diabetes was 4.9

(3.8) years. A total of 96 (47.3%) patients were in the least deprived quintiles, 54 (26.6%) patients in the moderately deprived quintile, and 53 (26.1%) in the most deprived quintiles. Thirty-seven percent were on insulin pump therapy and 81.3% had 3-4 diabetes-related physician visits in the year before their index visits.

HbA1c

The mean (SD) HbA1c in the total population was 8.3% (1.4%); 29.6% had an HbA1c below 7.5%. Mean HbA1c was highest in the most deprived SES group compared to the least deprived and moderately deprived SES groups (p=0.05). Mean HbA1c by SES was lower in patients on insulin pump therapy (Table 2) (p<0.05). The difference in HbA1c by number of diabetes-related physician visits was not statistically significant as shown in Table 3 (p=0.06).

Table 3. SES difference in mean HbA1c by pump status (yes/no)

Pump use	**Total**	**Q1+Q2**	**Q3**	**Q4+Q5**
Yes (n=76)				
HbA1c %, *mean (SD)*	7.9(1.0)	7.8(1.0)	7.9(1.0)	8.2(1.1)
No (n=127)				
HbA1c %, *mean (SD)*	8.5(1.5)	8.4(1.4)	8.4(1.5)	8.9(1.6)

p-value <0.05 by ANOVA

Table 4. SES differences in mean HbA1c by number of diabetes-related physician visits in the prior year

	Total	**Q1+Q2**	**Q3**	**Q4+Q5**
# MD visits < 3 (n=23)				
HbA1c %, mean (SD)	8.1(1.2)	7.7(0.9)	8.1(1.2)	8.9(1.6)
# MD visits 3-4 (n=165)				
HbA1c %, mean (SD)	8.3(1.4)	8.2(1.3)	8.2(1.3)	8.6(1.5)
# MD visits > 4 (n=15)				
HbA1c %, mean (SD)	9.1(1.6)	9.0(1.6)	8.2(1.2)	9.9(2.0)

p-value = 0.06 by ANOVA

SUBGROUPS

Ethnicity

Population characteristics for a subgroup with ethnicity by MSDI quintiles are shown in Table 5. The mean (SD) age was 13.4 (3.5) years and 51.9% were male. A total of 68.9% identified as White, 11.5% as Middle Eastern, 3.3% as Black, 8.7% as "Other" and 7.7% identified with more than one ethnicity (mixed). The 'other' group included the following self-reported ethnicities: East/Southeast Asian, Indigenous, Latino, South Asian, and other unspecified, and were grouped because of the small proportion for each ethnic group.

Mean (SD) duration of diabetes was 5 years (3.8), mean HbA1c was 8.2% (1.3%) and 30.6% had a mean HbA1c below 7.5%. A total of 47.5% were grouped in the least deprived quintiles, 26.2% in the moderately deprived quintile, and 26.2% in the most deprived quintiles. In total, 37.7% were on insulin pump therapy and 82.5% had 3-4 MD visits in the year prior.

Table 5. Patient Characteristics of the ethnicity subgroup

*Count less than 5

	Total = 183 (100%)	**Q1+Q2**	**Q3**	**Q4+Q5**	**p-value**
		N=87 (47.5%)	**N=48 (26.2%)**	**N=48 (26.2%)**	
Age (years), *mean (SD)*	13.4(3.5)	13.8 (3.1)	13.5 (3.5)	12.6 (4.0)	0.17
Sex (male), *n (%)*	95 (51.9)	41 (47.1)	28 (58.3)	26 (54.2)	0.43
Duration of diabetes (years), *mean (SD)*	4.9 (3.8)	5.1 (3.9)	4.6 (3.5)	4.9 (4.0)	0.82
Insulin pump *(yes), n (%)*	69 (37.7)	34 (39.1%)	21 (43.8%)	14 (29.2%)	0.32
# of MD clinic visits over the past 12 months, *mean (SD)*	3.5 (0.9)	3.4 (1.0)	3.5 (0.8)	3.5 (0.8)	0.65
# MD visits, *n (%)*					0.40

MD visits < 3, *n (%)*	20 (10.9)	12 (13.8)	*	5 (10.4)	
MD visits 3-4, *n (%)*	151 (82.5)	68 (78.2)	43 (89.6)	40 (83.3)	
MD visits > 4, *n (%)*	12 (6.6)	7 (8.0)	*	*	
HbA1c %, *mean (SD)*	8.2 (1.3)	8.1 (1.3)	8.1 (1.3)	8.6 (1.4)	0.15
HbA1c ≤ 7.5, *n (%)*	56 (30.6)	29 (33.3)	14 (29.2)	13 (27.1)	0.73
Ethnicity, *n (%)*					
Middle Eastern	21 (11.5)	8 (9.2)	*	9 (18.8)	
Black	6 (3.3)	*	*	*	
White	126 (68.9)	65 (74.7)	37 (77.1)	24 (50.0)	
Other	16 (8.7)	5 (5.7)	*	9 (18.8)	
Mixed	14 (7.7)	8 (9.2)	*	*	

As seen in Table 6, mean HbA1c was significantly higher in racialized ethnic groups (8.9% (1.5%)) compared to non-racialized ethnic groups (8.1% (1.2%)) ($p<0.01$).

Table 6. Mean HbA1c for racialized vs non racialized groups

	Total (N=183)	**Racialized (n=38)**	**Non-racialized (n=145)**	**p-value**
HbA1c % (SD)	8.2 (1.3)	8.9(1.5)	8.1 (1.2)	**<0.01**
HbA1c % ≤ 7.5, n (%)	56 (30.6)	7 (18.4)	49 (33.8)	0.13

Immigration status

A total of 113 patients reported parent and child immigration status (Table 7). Ninety-four (83.2%) parents and children were both non-immigrant/non-refugees, 9 (8.0%) children were immigrants with parents who were also immigrants, and 10 (8.8%) children were non-immigrants with parents who were immigrants.

Among non-immigrant children whose caregiver/parent was a non-immigrant, 51.0% reported English as the language that is most spoken at home, 44.7% reported French and 4.3% reported a language other than English and French. Among immigrant children whose parent

were also an immigrant, 11.1% reported English, 33.3% reported French, and 55.5% reported a language other than English and French. Among non-immigrant children whose parent was an immigrant, 30.0%, 30.0%, and 40.0% reported English, French or a language other than English or French, respectively, as the primary language spoken at home. HbA1c did not differ by immigration status (Table 7).

Table 7. Mean HbA1c by immigration status

*Count less than 5

	Total (N=113)	**Non-immigrant parent; non-immigrant child (N=94)**	**Immigrant parent; immigrant child (N=9)**	**Immigrant parent; non-immigrant child (N=10)**	**p-value**
Mean HbA1c % (SD)	8.3 (1.4)	8.2(1.3)	8.0 (1.2)	8.9 (2.2)	0.26
HbA1c ≤ 7.5, n (%)	36 (31.8)	29 (30.9)	5 (55.6)	*	0.23

Depression

Mean HbA1c was compared between those who screened positive for depression and those who screened negative across the three deprivation quintiles, as shown in Table 8. There was no significant difference in mean HbA1c by SES between those who screened negative for depression and those who screened positive for depression.

Table 8. Mean HbA1c of patients by depression screen results

	Total (n=192)	**Q1+Q2 (n=90)**	**Q3 (n=51)**	**Q4+Q5 (n=51)**
Positive depression screen (n=56)				
HbA1c %, mean (SD)	8.4 (1.2)	8.3 (0.9)	8.4 (1.3)	8.8 (1.6)
Negative depression screen (n=136)				
HbA1c %, mean (SD)	8.2 (1.3)	8.0 (1.3)	8.1 (1.3)	8.6 (1.4)

p-value = 0.20 by ANOVA

REGRESSION ANALYSIS

SES (MSDI) and mean HbA1c

The relationship between SES and HbA1c, adjusted for age, sex, diabetes duration, pump use, and processes of care was significant (Table 9). The multivariable linear regression model showed that mean HbA1c in the most deprived category was 0.51% higher than the mean HbA1c in the least deprived category (95% CI 0.05, 0.97). The use of insulin pumps was also significantly associated with lower mean HbA1c (adjusted ß = -0.55, 95% CI -0.96, -0.14). Having more than 4 diabetes-related clinic visits in the past year was associated with higher mean HbA1c compared to 3-4 visits (adjusted ß = 0.76, 95% CI 0.04, 1.48).

Table 9. Multivariable linear regression analysis for the association between SES and HbA1c, adjusted for sex, age, duration of diabetes, processes of care, and pump use

Variables	Estimates	95% CI	p-value
Least deprived – Q1+Q2	Reference	Reference	Reference
Moderately deprived Q3	0.05	-0.40, 0.51	0.82
Most deprived – Q4+Q5	0.51	0.05, 0.97	**0.03**
Sex (female)	0.09	-0.29, 0.48	0.63
Age	0.03	-0.04, 0.09	0.40
Duration of diabetes	-0.01	-0.07, 0.05	0.86
On pump	-0.55	-0.96, -0.14	**0.01**
MD visits 3-4	Reference	Reference	Reference
MD visits < 3	-0.23	-0.83, 0.37	0.45
MD visits > 4	**0.76**	**0.04, 1.48**	**0.04**

Interaction between SES and insulin pump use, processes of care, depression

The interaction terms between SES and insulin pump status (Table 10), and SES and processes of care (Table 11) were not significant.

Table 10. Multivariable linear regression SES and HbA1c – interaction term between SES and insulin pump

Variables	Estimates	95% CI	p-value
Pump use: NO			
Least deprived – Q1+Q2 (Ref)	Reference	Reference	Reference
Moderately deprived - Q3	0.10	-0.77, 0.98	1.00
Most deprived – Q4+Q5	0.54	-0.28, 1.36	0.41

Pump use: YES			
Least deprived – Q1+Q2 (Ref)	Reference	Reference	Reference
Moderately deprived - Q3	-0.02	-1.06, 1.02	1.00
Most deprived – Q4+Q5	0.46	-0.75, 1.68	0.88
MD visits 3-4	Reference	Reference	Reference
MD visits < 3	-0.23	-0.84, 0.37	0.45
MD visits > 4	**0.77**	**0.04, 1.50**	**0.04**
Sex (female)	0.10	-0.29, 0.48	0.62
Age	0.03	-0.04, 0.09	0.39
Duration of diabetes	-0.01	-0.07, 0.05	0.83

Table 11. Multivariable linear regression SES and HbA1c – interaction term between SES and processes of care

Variables	Estimates	95% CI	p-value
MD visits < 3			
Least deprived – Q1+Q2	Reference	Reference	Reference
Moderately deprived - Q3	0.27	-2.17, 2.71	1.00
Most deprived – Q4+Q5	1.3	-0.84, 3.36	0.63
MD visits 3-4			
Least deprived – Q1+Q2	Reference	Reference	Reference
Moderately deprived - Q3	0.04	-0.75, 0.83	1.00
Most deprived – Q4+Q5	0.37	-0.44, 1.19	0.89
MD visits > 4			
Least deprived – Q1+Q2	Reference	Reference	Reference
Moderately deprived - Q3	-0.32	-3.29, 2.64	1.00
Most deprived – Q4+Q5	0.85	-1.76, 3.47	0.98
On pump	**-0.52**	**-0.95, -0.10**	**0.02**
Sex (female)	0.11	-0.28, 0.49	0.56
Age	0.03	-0.03, 0.09	0.37
Duration of diabetes	-0.01	-0.07, 0.05	0.83

In a subgroup with information on depression screening, the relationship between SES and HbA1c, adjusted for age, sex, diabetes duration, pump use, processes of care, and depression, the multivariable linear regression model showed that HbA1c in the most deprived quintiles was 0.49% higher than the mean HbA1c in the least deprived category (95% CI 0.05, 0.93; Table 12). Insulin pump use was associated with lower HbA1c (adjusted ß = -0.54, 95% CI -0.93, -0.15) and having more than 4 diabetes-related physician visits was associated with higher HbA1c (adjusted ß = 0.98, 95% CI 0.29, 1.67).

The multivariable linear regression model with the interaction term between SES and depression screen showed no effect modification of depression on HbA1c (Table 13).

Table 12. Multivariable linear regression analysis for the association between SES and HbA1c, adjusted for sex, age, duration of diabetes, processes of care, pump use, and depression

[a]Linear regression analysis was done with a subgroup (n=192) that had information on depression screening

Variables	Estimates	95% CI	p-value
Least deprived – Q1+Q2 (Ref)	Reference	Reference	Reference
Moderately deprived Q3	0.17	-0.27, 0.60	0.45
Most deprived – Q4+Q5	**0.49**	**0.05, 0.93**	**0.03**
Sex (female)	-0.08	-0.44, 0.28	0.67
Age	0.01	-0.05, 0.06	0.86
Duration of diabetes	0.00	-0.06, 0.06	0.97
On pump	-0.54	-0.93, -0.15	**0.01**
MD visits 3-4	Reference	Reference	Reference
MD visits < 3	-0.11	-0.67, 0.46	0.71
MD visits > 4	**0.98**	**0.29, 1.67**	**0.01**
Positive depression screen	0.18	-0.21, 0.58	0.36

Table 13. Multivariable linear regression SES and HbA1c – interaction term between SES and depression

[a]Linear regression analysis was done with a subgroup (n=192) that had information on depression screening

Variables	Estimates	95% CI	p-value
Depression: NO			
Least deprived – Q1+Q2	Reference	Reference	Reference
Moderately deprived Q3	0.14	-0.63, 0.91	1.00
Most deprived – Q4+Q5	0.56	-0.18, 1.30	0.26
Depression: YES			
Least deprived – Q1+Q2	Reference	Reference	Reference
Moderately deprived Q3	0.22	-0.91, 1.36	0.99
Most deprived – Q4+Q5	0.27	-0.99, 1.54	0.99
On pump	**-0.54**	**-0.93, -0.15**	**0.01**
MD visits 3-4	Reference	Reference	Reference
MD visits < 3	-0.11	-0.68, 0.46	0.71
MD visits > 4	**1.02**	**0.32, 1.73**	**<0.01**
Sex (female)	-0.07	-0.44, 0.30	0.71
Age	0.00	-0.06, 0.06	0.96

Duration of diabetes	0.00	-0.05, 0.06	0.90

Ethnicity and HbA1c

In a subgroup of patients that had reported ethnicity, mean HbA1c was higher in patients in racialized groups compared to those in non-racialized groups (adjusted ß = 0.70, 95% CI 0.21,1.18), controlling for SES, age, sex, diabetes duration, insulin pump use, and processes of care.

Table 14. Multivariable linear regression of ethnicity and HbA1c, adjusted for sex, age, duration of diabetes, and SES

Variables	Estimates	95% CI	p-value
Least deprived – Q1+Q2	Reference	Reference	Reference
Moderately deprived - Q3	0.03	-0.42, 0.48	0.90
Most deprived - Q4+Q5	0.23	-0.24, 0.70	0.33
Sex (female)	0.01	-0.38, 0.39	0.98
Age	0.01	-0.05, 0.08	0.71
Duration of diabetes	0.00	-0.06, 0.06	0.97
Racialized	**0.70**	**0.21, 1.18**	**0.01**
On pump	**-0.44**	**-0.84, -0.04**	**0.03**
MD visits 3-4	Reference	Reference	Reference
MD visits < 3	-0.22	-0.82, 0.39	0.48
MD visits > 4	1.13	0.37, 1.90	**<0.01**

Immigration and HbA1c

In the adjusted regression analysis (Table 15), in the groups where both children and their parents were immigrants, the mean HbA1c was 0.28% lower compared to the group consisting of non-immigrant parent and child, however, this effect was not significant (95% CI -1.22, 0.66). Non-immigrant children with parents who were immigrants had a mean HbA1c of 0.54% higher compared to non-immigrant parents and children, this effect was also not significant (95% CI -0.39,1.47).

Table 15. Multivariable linear regression analysis examining association of immigration status with HbA1c

Predictors	Estimates	95% CI	p-value
Least deprived – Q1+Q2	Reference	Reference	Reference
Moderately deprived - Q3	0.27	-0.38,0.92	0.41
Most deprived – Q4+Q5	0.25	-0.36,0.87	0.41
Sex (female)	-0.29	-0.84,0.26	0.29
Age	0.02	-0.07,0.11	0.70
Duration of diabetes	-0.01	-0.09,0.07	0.83
Non-immigrant parent & patient	Reference	Reference	Reference
Immigrant Parent & Patient	-0.28	-1.22,0.66	0.55
Immigrant Parent & non-immigrant patient	0.54	-0.39,1.47	0.25
On pump	**-0.61**	**-1.17, -0.04**	**0.04**
MD visits 3-4	Reference	Reference	Reference
MD visits < 3	-0.10	-0.97,0.77	0.82
MD visits > 4	**1.04**	**0.14, 1.94**	**0.02**

Sensitivity analysis: SES MEASURED BY THE CIMD

After linking the PCCF to CIMD quintiles, 4 patients were excluded for a postal code that was not assigned a quintile; a deprivation quintile was determined for a total of 208 patients.

Patient characteristics

Patients had a mean (SD) age of 13.5 (3.5) years and mean (SD) diabetes duration of 4.9 (3.8) years; 53.4% were male and 37.5% were on an insulin pump. The mean number of diabetes-related physician visits in the year before the index visit was 3.8 (±0.9). The mean (SD) HbA1c was 8.3% (1.4%) and 29.8% had a mean HbA1c below 7.5%. The patient characteristics by quintile in each dimension of the CIMD are presented in Table 16-19.

Table 16. Patient characteristics: residential instability dimension
*Count less than 5

	Total = 208	**Q1+Q2**	**Q3**	**Q4+Q5**	**p-value**
		N=107	**N=32**	**N=69**	
Age (years), *mean (SD)*	13.5 (3.5)	14.0 (3.3)	13.6 (2.9)	12.8 (3.9)	0.10
Sex (male), *n (%)*	111 (53.4)	57 (53.3)	13 (40.6)	41 (59.4)	0.21
Duration of diabetes (years), *mean (SD)*	4.9 (3.8)	5.3 (4.0)	5.0 (3.5)	4.4 (3.7)	0.33
Insulin pump (yes), *n (%)*	78 (37.5)	42 (39.3)	14 (43.8)	22 (31.9)	0.45
# of MD clinic visits over the past 12 months, *mean (SD)*	3.8 (0.9)	3.7 (0.9)	3.7 (0.7)	3.9 (0.9)	0.18
# MD visits, *n (%)*					0.29
< 3 visits, n (%)	10 (4.8)	*	*	*	
3-4 visits, n (%)	173 (83.2)	92 (86.0)	28 (87.5)	53 (76.8)	
> 4 visits, n (%)	25 (12.0)	10 (9.3)	*	13 (18.8)	
HbA1c %, *mean (SD)*	8.3 (1.4)	8.1(1.2)	8.4(1.3)	8.6(1.6)	0.13
HbA1c ≤ 7.5, *n (%)*	62 (29.8)	38 (35.5)	8 (25.0)	16 (23.2)	0.18

Table 17. Patient characteristics: situational vulnerability
*Count less than 5

	Total = 208	**Q1+Q2**	**Q3**	**Q4+Q5**	**p-value**
		N=126	**N=30**	**N=52**	
Age (years), *mean (SD)*	13.5 (3.5)	14.0 (3.1)	13.2 (4.1)	12.5 (3.8)	0.03
Sex (male), *n (%)*	111 (53.4)	67 (53.2)	17 (56.7)	27 (51.9)	0.92
Duration of diabetes (years), *mean (SD)*	4.9 (3.8)	5.0 (4.0)	5.1 (3.7)	4.6 (3.6)	0.72
Insulin pump (yes), n (%)	78 (37.5)	54 (42.9)	10 (33.3)	14 (26.9)	0.12
# of MD clinic visits over the past 12 months, *mean (SD)*	3.8 (0.9)	3.8 (0.8)	3.6 (0.9)	3.9 (1.0)	0.30
# MD visits, *n (%)*					0.71
< 3 visits, *n (%)*	10 (4.8)	*	*	*	
3-4 visits, *n (%)*	173 (83.2)	107 (84.9)	26 (86.7)	40 (76.9)	
> 4 visits, *n (%)*	25 (12.0)	14 (11.1)	*	8 (15.4)	
HbA1c %, *mean (SD)*	8.3 (1.4)	8.1(1.3)	8.5(1.2)	8.7(1.5)	**0.02**
HbA1c ≤ 7.5, n (%)	62 (29.8)	43 (34.1)	9 (30.0)	10 (19.2)	0.14

Table 18. Patient characteristics: economic dependency
*Count less than 5

	Total = 208	Q1+Q2	Q3	Q4+Q5	p-value
		N=117	N=38	N=53	
Age (years), *mean (SD)*	13.5 (3.5)	13.6 (3.3)	13.3 (3.8)	13.5 (3.8)	0.91
Sex (male), *n (%)*	111 (53.4)	60 (51.3)	17 (44.7)	34 (64.2)	0.15
Duration of diabetes (years), *mean (SD)*	4.9 (3.8)	4.8 (3.9)	5.6 (3.9)	4.7 (4.1)	0.47
Insulin pump (yes), *n (%)*	78 (37.5)	48 (41.0)	14 (36.8)	16 (30.2)	0.40
# of MD clinic visits over the past 12 months, *mean (SD)*	3.8 (0.9)	3.7 (0.8)	4.1 (1.2)	3.7 (0.7)	**0.05**
# MD visits, *n (%)*					0.10
< 3 visits, *n (%)*	10 (4.8)	*	*	*	
3-4 visits, *n (%)*	173 (81.2)	102 (87.2)	26 (66.6)	45 (84.9)	
> 4 visits, *n (%)*	25 (12.0)	11 (9.4)	9 (23.1)	5 (9.4)	
HbA1c %, *mean (SD)*	8.3 (1.4)	8.2(1.4)	8.5(1.3)	8.5(1.5)	**0.02**
HbA1c ≤ 7.5, n (%)	62 (29.8)	40 (34.2)	9 (23.7)	13 (24.5)	0.29

Table 19. Patient characteristics: ethnocultural composition
*Count less than 5

	Total = 208	Q1+Q2	Q3	Q4+Q5	p-value
		N=19	N=31	N=158	
Age (years), *mean (SD)*	13.5 (3.5)	13.3 (2.8)	13.2 (3.9)	13.6 (3.5)	0.85
Sex (male), *n (%)*	111 (53.4)	9 (47.4)	15 (48.4)	87 (55.1)	0.68
Duration of diabetes (years), *mean (SD)*	4.9 (3.8)	5.1 (4.1)	5.6 (3.6)	4.8 (3.9)	0.53
Insulin pump (yes), *n (%)*	78 (37.5)	9 (47.4)	13 (41.9)	56 (35.4)	0.63
# of MD clinic visits over the past 12 months, *mean (SD)*	3.8 (0.9)	3.7 (0.8)	3.6 (0.7)	3.8 (0.9)	0.51
# MD visits, *n (%)*					0.55
< 3 visits, *n (%)*	10 (4.8)	*	*	6 (3.8)	
3-4 visits, *n (%)*	173 (83.2)	15 (78.9)	27 (87.1)	131 (82.9)	
> 4 visits, *n (%)*	25 (12.0)	*	*	21 (13.3)	
HbA1c %, *mean (SD)*	8.3 (1.4)	9.0(1.6)	7.9(1.3)	8.3(1.3)	**0.03**
HbA1c ≤ 7.5, *n (%)*	62 (29.8)	*	11 (35.5)	48 (30.4)	0.32

Regression analysis

A higher mean HbA1c was seen in higher levels of deprivation in measures of situational vulnerability; patients in the most deprived quintiles had a mean HbA1c 0.56% higher than patients in the least deprived quintiles (95% CI 0.12,1.00). The effect of deprivation in measures of economic dependency and residential instability was not significant (Table 20). Deprivation in the ethnocultural composition dimension was associated with a lower mean HbA1c; patients in the moderately diverse quintile (Q3) had a mean HbA1c 1.11% lower compared to the least deprived (95% CI -1.86, -0.35) and patients in the most diverse quintiles had a mean HbA1c 0.84% lower compared to the least deprived (95% CI -1.47, -0.21).

Table 20. Multivariable linear regression analysis examining association of SES with HbA1c by each dimension of the CIMD

	Residential instability			**Situational Vulnerability**			**Economic Dependency**			**Ethnocultural composition**		
Variables	Estimates	95% CI	p-value	Estimates	95% CI	p-value	Estimates	95% CI	p-value	Estimates	95% CI	p-value
Least deprived – Q1+Q2	Reference	-	-	Reference	-	-	Reference	-	-	Reference	-	-
Moderately deprived Q3	0.31	-0.22, 0.84	0.25	0.33	-0.21, 0.86	0.23	0.22	-0.28, 0.72	0.39	-1.11	-1.86, -0.35	**<0.01**
Most deprived – Q4+Q5	0.34	-0.08, 0.75	0.11	0.56	0.12, 1.00	**0.01**	0.31	-0.13, 0.75	0.17	-0.84	-1.47, - 0.21	**0.01**
Sex (female)	0.09	-0.29, 0.46	0.65	0.09	-0.28, 0.45	0.64	0.10	-0.27, 0.47	0.59	0.07	-0.29, 0.43	0.70
Age	0.02	-0.04, 0.08	0.57	0.03	-0.03, 0.09	0.39	0.01	-0.05, 0.08	0.66	0.01	-0.05, 0.07	0.70
Duration of diabetes	0.00	-0.05, 0.06	0.89	-0.00	-0.06, 0.05	0.90	0.00	-0.06, 0.06	0.98	0.01	-0.05, 0.06	0.86
On pump	-0.55	-0.95, -0.15	**0.01**	-0.48	-0.88, -0.08	**0.02**	-0.52	-0.92, -0.12	**0.01**	-0.58	-0.98, -0.19	**<0.01**
MD visits 3-4	Reference	-	-	Reference	-	-	Reference	-	-	Reference	-	-
MD visits < 3	-0.54	-1.40, 0.32	0.22	-0.60	-1.46, 0.25	0.17	-0.58	-1.44, 0.29	0.19	-0.61	-1.46, 0.24	0.16
MD visits > 4	0.72	0.15, 1.29	**0.01**	0.74	0.17, 1.30	**0.01**	0.75	0.17, 1.32	**0.01**	0.75	0.20, 1.31	**0.01**

SENSITIVITY ANALYSIS – Insulin pump use

When we defined insulin pump use as being on a pump at the index visit for at least 6 months, and at least 50% of the visits, the interaction term remained nonsignificant (Appendix 3).

4.5 Discussion

Material and Social Deprivation and Situational Vulnerability

The current study evaluated the effect of SES on glycemic control using two comprehensive area-level measures of deprivation. Our findings demonstrate differences in glycemic control between levels of deprivation using the MSDI, as well as the CIMD dimensions of situational vulnerability and ethnocultural composition of the CIMD. Children in the most deprived quintiles had higher mean HbA1c compared to children in the least deprived quintiles with the MSDI and on the CIMD dimension of situational vulnerability but not economic dependency and residential instability; the constructs that were measured may not be associated with diabetes outcomes in this sample. In addition, the moderately and most deprived (diverse) quintiles of ethnocultural compositions were associated with lower HbA1c compared to the lowest deprived quintiles.

The overall results of this study are consistent with findings reported of SES and glycemic control in children with T1D.[60] One study that measured SES by household income found that children (<17 years) from lower SES had a higher mean HbA1c (8.55%, 95% CI 8.45,8.65%) compared to individuals from higher SES (7.20%, 95% CI 6.75, 7.65%) despite universal financial coverage for health care.[48,60] The retrospective cohort study only measured one dimension of deprivation (household income), which does not reflect all relevant aspects of deprivation. Also, the analysis did not account for other confounding factors such as use of insulin pumps and access to care. In the present study, the use of the MSDI creates a comprehensive measure of SES that accounts for multiple aspects of deprivation including but not limited to household income. Furthermore, we were able to demonstrate the effect of SES on HbA1c adjusting for insulin pump use, an important factor to consider for the observed effect. This replicated findings from other Canadian data of 854 children with T1D that also reported an association between greater compared to lower levels of deprivation and poorer glycemic control (0.27%, p=0.04) after adjusting for insulin pump use, in a cohort where patients had a median number of 3 diabetes-related clinic visits.[48] This was a retrospective cohort study of children living with T1D followed from August 2010 to August 2011 using the MSDI and the CIMD's ethnocultural composition dimension. Our study contributes to up-to-date evidence of the association between SES and glycemic control using recent Census data.

Effect modification by pump use

We observed overall that children who used an insulin pump had significantly lower mean HbA1c regardless of deprivation quintile. We hypothesized that the use of an insulin pump would modify the effect of SES on mean HbA1c. However, the interaction term was not significant.

Previous studies have found insulin pump use to be an important factor for glycemic control in children of low SES.[48,66] For example, Zuijdwijk et al.'s study mentioned above also found that insulin pump use modified the effect of SES on mean HbA1c, and was associated with lower HbA1c for children in the most deprived quintiles compared to being off the pump.[48] Also, Senniapan et al. found that among those who used an insulin pump, there was no significant increase in mean HbA1c for children with parents with the lowest level of education compared to patients of the highest education level.[66] The authors concluded that those who generally have suboptimal glycemic control could benefit the most from the use of insulin pumps.

In our analysis, we were able to evaluate how insulin pump use modifies the relationship between SES and glycemic control. Although low SES children who were on an insulin pump had better glycemic control compared to those who were not, they were also underrepresented among those who were on an insulin pump. Even with universal funding for pumps, SES disparities persist suggesting that there are factors beyond financial barriers that affect pump use among individuals of low SES which could include aspects related to community support or specific lifestyle constraints. Further investigation is needed to first address these disparities in insulin pump use and determine which other factors could contribute to the effect of insulin pump therapy among children of low SES.

Effect modification by processes of care

We hypothesized that having at least 3-4 physician visits in the past year, an indication of adherence to guidelines, would modify the effect of SES on mean HbA1c. However, we found no significant association between the interaction of SES with the number of physician visits and

mean HbA1c. Our data also showed that there was no significant difference in mean HbA1c between children with less than 3 diabetes-related clinic visits in the past year, those with 3 or 4, and those with more than 4. However, adjusted multivariable linear regression showed that having more than 4 visits was significantly associated with a higher HbA1c.

An older cohort study of children and adolescents with T1D found that continuous follow-ups (having at least one diabetes-related clinic visit per year during the 2-4 years of follow up) was associated with improved glycemic control compared to irregular follow ups which was defined as failing to have at least one diabetes-related clinic visit during the 2-4 years of follow up.[79] In addition, a 2014 retrospective longitudinal cohort study of youth with T1D also reported that children with Medicaid, indicative of low SES in the U.S., were more likely to have worsened glycemic control and also had fewer visits and HbA1c tests.[67] However, insulin regimen was not accounted for in the analysis.

Our study addressed the interaction between processes of care and SES on glycemic control in the context of Quebec's health care system and we examined whether children who have regular checkups, which entails more opportunities to discuss treatment plans, HbA1c measurements, and screening for complications, have better glycemic control. Although frequent follow-ups have been shown to improve glycemic control, our data showed that having more than 4 visits was significantly associated with higher mean HbA1c which may reflect children who have suboptimal glycemic control and are monitored more frequently. Urbach et al. reported similar results in a cross-sectional study of children with T1D where children who attended diabetes clinic more than five times in the previous year had significantly higher HbA1c levels compared to those who had three or four visits (95% CI 0.23,1.20).[80] Contrary to these findings, we did not observe a significant difference between those who had less than 3 visits and those who had 3-4 visits, largely due to the small group size with less than 3 visits.

Effect modification by depression symptoms

Based on previous studies, we hypothesized that children in the least deprived quintiles who also screened positive for depression would have worse glycemic control, which would emphasize the importance of screening for mental health and implementation of strategies to address the

issue in children with T1D. We found that the interaction between SES and depressive symptoms was not significant in our cohort.

Walker et al. found that youth of lower SES often lacked resources for social support and therefore may be at a greater risk of experiencing mental health issues such as depression and isolation that hinder effective glycemic control.[81] In a cross-sectional study of children aged 8-17 years, Hassan et al. reported that depression was more likely among children with poor glycemic control and that children of low SES were most at risk of poor glycemic control.[82]

Our study evaluated the effect of depressive symptoms on glycemic control through an interaction, in children who were followed for a year. We did not observe a significant effect modification in our sample which may be due to the small number of children in the low SES group, and different stressors may affect both children of low and high SES making them susceptible to experience depressive symptoms. Also, the PHQ-2 is a screening tool for depressive symptoms in the preceding two weeks; it is possible that the full range of depressive symptoms that may affect diabetes management and outcomes was not captured.

Ethnicity and HbA1c

We observed ethnic disparities in glycemic control in the sample which is consistent with previous studies in the U.S. and UK that have found ethnic/racial disparities in treatment and outcomes. Specifically, we observed that racialized groups had worse glycemic control compared to non-racialized groups.

In a retrospective cohort study of children (<18 years), Lipman et al. found that Non-Hispanic Black patients had higher HbA1c levels (9.4%) compared to Non-Hispanic White patients (8.6%, $p<0.001$) and that this difference persisted within insurance groups.[62] Racialized individuals had higher mean HbA1c compared to non-racialized individuals when adjusting for SES. The observed differences are likely due to structural and social determinants of health rather than biological differences. Results of structural racism, differential use of resources and social support are factors that contribute to racial and ethnic disparities in health outcomes.[65,83]

Thompson et al. found that HbA1c was associated with ethnicity rather than deprivation, which may be explained by the mode of insulin therapy between ethnic groups.[32] This supports the need for addressing differences in outcomes by understanding barriers that disproportionally affect racialized groups[83] as well understanding the views and needs of different ethnic groups concerning health care and disease management.

Our study reports an important finding of existing ethnic and racial disparities in children with T1D considering limited Canadian studies that have addressed them. These findings are important to develop policies and interventions aimed at addressing structural racism in health care.

Ethnicity, ethnocultural composition and HbA1c

We found that ethnocultural composition was associated with lower HbA1c levels in moderately and most deprived (diverse) quintiles. With the ethnocultural composition being an indication of the concentration of ethnic minorities in each DA's, this finding suggests that we may observe better glycemic control in children from areas with a higher concentration of minorities and immigrant family dwellings. Contrary to our result that racialized groups have worse glycemic control, where self-reported ethnicity is an individual-level measure, a neighbourhood-level measurement of ethnocultural composition highlights a different aspect of social determinants of health. Our finding that more diverse ethnocultural composition is associated with lower HbA1c could be explained by the positive impact of neighbourhood diversity and social cohesion on health outcomes.

Studies in Canada and the UK have addressed the question of ethnic density and children's overall health to determine whether the health of children is influenced by living around people with similar ethnic backgrounds but results are inconsistent as this association differs by ethnicity, gender, and ethnic concentration. [84,85,86,87]

Limitations

There were several limitations to this study. First, the use of clinical data from March 2020, during restrictions related to the COVID-19 pandemic resulted in many appointments to be cancelled or held via telephone which prevented HbA1c to be measured for some subjects included in the study. Consequently, children included did not have the same number of HbA1c measurements during the study period. Another limitation is the use of a population-level measure to measure individual SES; DAs are heterogeneous and may not accurately represent the level of deprivation of each household in one specific area. Nonetheless, area-level deprivation has been a useful and accurate measure in previous studies that have demonstrated health inequalities.[88] Furthermore, measures of deprivation were based on data from the 2016 Canadian Census and therefore do not provide an up-to-date representation of levels of deprivation in the areas determined by the postal codes obtained during the study period. In addition, we did not include the use of CGM systems as a variable in our analyses as our study overlapped with a period where government financial coverage for CGM systems was not standardized as such CGM access was inconsistent during our study period. Another limitation is the optional self-identification of ethnicity and immigration status in our subgroup, which lead to a smaller sample size for this subgroup; we may not have captured the full effect of these variables.

4.6 Conclusion

There is substantial evidence that health outcomes in children with T1D are affected by socioeconomic and ethnic disparities. Further studies are needed to determine drivers of these inequalities within health care and determine factors that help diminish them. For example, community health workers or patient navigators have shown promise in addressing health disparities in chronic conditions which should be further explored in a Canadian health care system. Also, there are opportunities to examine the different health impacts of neighborhood-level ethnic composition on racialized communities.

5 Discussion

Restatement of objectives and summary of findings

This thesis mainly focused on examining the question of health disparities in children with T1D in Montreal, by first looking at SES and glycemic control with the use of a validated index, assessing modifiers of this relationship, and examining ethnic disparities in glycemic control as well as differences by immigration status. The primary objective sought to determine the association between SES and glycemic control. The secondary objectives sought to determine whether insulin pump use, processes of care, and depression modified the relationship between SES and mean HbA1c. As part of the secondary objectives, we also sought to determine the association between ethnicity, immigration and HbA1c.

Chapter 4 addressed the objectives of this thesis and suggested that low SES is associated with higher HbA1c and that effect modification by insulin pump use, processes of care, and depression was not significant. Additionally, ethnic disparities were evident in the sample; racialized groups had higher HbA1c compared to non-racialized groups. We also observed that higher ethnocultural composition was associated with lower HbA1c.

Summary of contribution and directions for future research

Health inequalities are attributable to differences in structural and social determinants of health (SDOH), that dictate individuals' opportunities to manage health conditions such as T1D. Numerous studies have demonstrated that socioeconomic status and ethnicity are associated with poor glycemic control. Few studies investigated this question while considering the Canadian health care system. Furthermore, few Canadian studies have sought to determine variables that interact with these SDOH and modify their effect on health outcomes. Through a retrospective cohort study using a patient database from the Montreal Children's Hospital in Montreal, we were able to evaluate health disparities in children aged 0 to 18 years by examining the association of SES with mean HbA1c, effect modification by insulin pump use, processes of care, and depression, as well as the effect of ethnicity and immigration status on glycemic control. This research calls attention to the impact of differences in social determinants on health outcomes given the Canadian health care system and the importance of addressing factors beyond individual characteristics that can affect T1D diabetes and outcomes.[65] The management of chronic diseases such as T1D can be costly and require access to additional resources and supports that may be difficult to obtain among families of low SES, even with financial coverage

for available technologies. The findings help to highlight potential social barriers that contribute to differential access to care, technology uptake, and delivery of care such as implicit bias from health care professionals towards specific groups of patients. For example, the smaller proportion of low SES individuals using an insulin pump is a possible result of prescribing bias and health care provider bias, which can also affect individuals of racialized communities.

In chapter 4, we determined that children of lower SES had worse glycemic control and the use of insulin pumps did not modify this association, despite the availability of government reimbursement programs in Quebec. Although insulin pump use is more common in regions with funding programs, socioeconomic and ethnic disparities exist between users and non-users.[89] It is necessary to determine factors that affect the uptake of technologies such as specific lifestyles and cultural differences, to explore ways that healthcare professionals can address specific needs and views on disease management, and to address biases by health care providers in regard to offering insulin pumps to children of low SES and of racialized groups.

In addition to technology use, mental health factors may also play a role in differences seen in diabetes health outcomes. We investigated whether screening positive for depression put children of low SES at a greater risk of poor glycemic control compared to children of high SES; an interaction between SES and depression screen was not found in our sample. Further studies could identify differences in symptom severity, management of symptoms and access to mental health resources across SES groups and determine the impact of these factors on disparities in health outcomes.

Furthermore, we determined that ethnicity was associated with worse glycemic control while the ethnocultural composition was associated with better glycemic control. This suggests the need to examine the impact of neighbourhood and community on the health of racialized populations; racially diverse areas may benefit racialized groups through increased social cohesion and availability of resources and community programs.

Future research should explore ways to better address structural and SDOH in diabetes care that contribute to inequitable outcomes in T1D. For example, community health workers or patient

navigators have shown promise in addressing health disparities in chronic conditions. Community health workers or patient navigators act as a connection for families between medical, social, and community services, and support families by helping improving adherence and access to treatments, reducing food and housing insecurity, and improving health literacy. A pilot randomized controlled trial is currently underway in the U.S. to determine the effect of community health workers on HbA1c and health services utilization among T1D children.[90] Such roles have yet to be integrated into diabetes care teams in Canada.

Limitations

There were several limitations to acknowledge. First, population-level data was used to estimate SES as opposed to using individual-level data. However, the MSDI and CIMD are standard methods of measuring health inequalities in Canadian data. Also, we were not able to capture the full effect of ethnicity, immigration status, and depression in the sample because reporting this information was optional for families. Due to the pandemic, different modes of health care delivery (i.e. more virtual visits) resulted in missing HbA1c measurements for some subjects included in the study, consequently children included did not have the same number of HbA1c measurements during the study period.

Conclusion

In conclusion, the thesis highlighted existing health disparities in diabetes outcomes for children with T1D, aged 0 to 18 years living in Montreal. The thesis showed the association between SES and glycemic control and that children of low SES have significantly higher mean HbA1c compared to children of high SES. Further studies are needed to investigate factors that contribute to these inequalities in this population to develop interventions that may address them.

6 REFERENCES

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7 Appendices

Appendix 1: Main population characteristics

Table 1.
Population characteristics of children who were excluded for having a postal code not assigned to DA

	Total = 6
Age (years), mean (SD)	15.2 (2.2)
Sex (male), n (%)	3 (50.0)
Duration of diabetes (years), mean (SD)	7.8 (3.7)
Insulin pump (yes), n (%)	2 (33.3)
# of MD clinic visits over the past 12 months, mean (SD)	3.0 (1.6)
MD visits ≥ 3, n (%)	5 (83.3)
HbA1c %, mean (SD)	8.5 (1.0)
HbA1c ≤ 7.5, n (%)	2 (33.3)

Appendix 2: Selection of subgroups

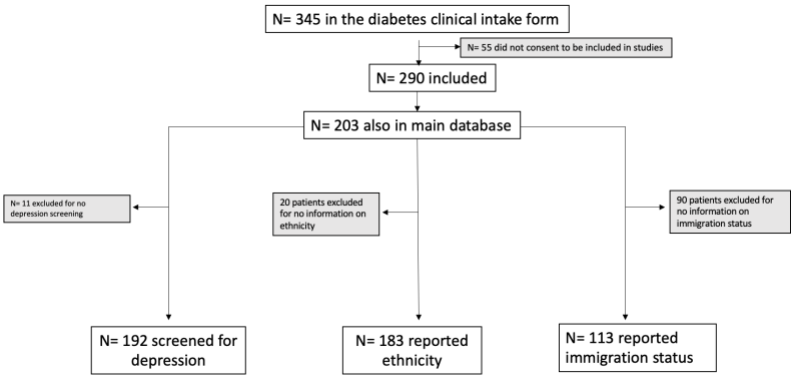

Figure 1. Flowchart of population selection for subgroup analysis

Appendix 3: Sensitivity analysis

Table 2. Insulin pump use by SES quintile for children who were on the pump for at least 6 months before index visit, and were on the pump for at least 50% of their visits in the year following the index visit (either got on the pump or off the pump)

	Total (N=203)	**Q1 + Q2 (N=96)**	**Q3 (N=54)**	**Q4 + Q5 (N=53)**	**p-value**

Insulin pump (yes), *n* (%)	78 (38.4)	41 (42.7)	23 (42.6)	14 (26.4)	0.11

Table 3. Multivariable linear regression analysis for the association between SES and HbA1c, adjusted for sex, age, duration of diabetes, processes of care, and insulin pump use for at least 50% of visits

Variables	Estimates	95% CI	p-value
Least deprived – Q1+Q2	Reference	Reference	Reference
Moderately deprived Q3	0.04	-0.42, 0.50	0.86
Most deprived – Q4+Q5	0.51	0.05, 0.98	**0.03**
Sex (female)	0.09	-0.29, 0.48	0.63
Age	0.03	-0.03, 0.09	0.38
Duration of diabetes	-0.01	-0.07, 0.05	0.74
On pump	-0.47	-0.88, -0.06	**0.03**
MD visits 3-4	Reference	Reference	Reference
MD visits < 3	-0.23	-0.84, 0.37	0.45
MD visits > 4	0.79	0.07, 1.51	**0.03**

Table 4. Multivariable linear regression SES and HbA1c – interaction term between SES and insulin pump use for at least 50% of visits

Variables	Estimates	95% CI	p-value
Pump use: NO			
Least deprived – Q1+Q2	Reference	Reference	Reference
Moderately deprived - Q3	0.16	-0.73, 1.04	1.00
Most deprived – Q4+Q5	0.59	-0.23, 1.42	0.31
Pump use: YES			
Least deprived – Q1+Q2	Reference	Reference	Reference
Moderately deprived - Q3	-0.12	-1.15, 0.91	1.00
Most deprived – Q4+Q5	0.37	-0.84, 1.58	0.95
MD visits 3-4	Reference	Reference	Reference
MD visits < 3	-0.24	-0.84, 0.37	0.44
MD visits > 4	0.81	0.07, 1.54	**0.03**
Sex (female)	0.10	-0.29, 0.48	0.62
Age	0.03	-0.03, 0.09	0.37
Duration of diabetes	-0.01	-0.07, 0.05	0.68