

Contents lists available at [ScienceDirect](https://www.sciencedirect.com)

Canadian Journal of Diabetes

journal homepage:
www.canadianjournalofdiabetes.com


Original Research

Exploring Knowledge and Safety Practices for Driving in Youth With Type 1 Diabetes



Kathryn Potter MD^a; Heidi Virtanen MSc^a; Fiona Stewart MD^a; Paola Luca MD^{a,b,c};
Josephine Ho MD^{a,b,c}; Alberto Nettel-Aguirre PhD^{a,b,c}; Danièle Pacaud MD^{a,b,c,*}

^a Department of Pediatrics, Alberta Children's Hospital, Calgary, Alberta, Canada^b Department of Pediatrics, University of Calgary, Calgary, Alberta, Canada^c Alberta Children's Hospital Research Institute, Calgary, Alberta, Canada

Key Messages

- Individuals with type 1 diabetes (T1D) and youth are both more likely than the average driver to be involved in motor vehicle collisions.
- Youth with T1D have good knowledge on safety practices for driving with diabetes, but were less likely to practice these safety measures as they graduated to a full license.
- Regular review of barriers and challenges to adherence to safety practices should be incorporated into clinical practice.

ARTICLE INFO

Article history:

Received 7 March 2019
Received in revised form
24 May 2019
Accepted 3 June 2019

Keywords:

adolescent
driving
type 1 diabetes

Mots clés:

adolescent
conduite
diabète de type 1

ABSTRACT

Objectives: The aim of this work was to survey how well adolescents with type 1 diabetes mellitus (T1D) of legal driving age understand the risks associated with driving with diabetes and report adherence to recommendations.

Methods: This study was a cross-sectional survey of 191 adolescents, 14 to 18 years of age, with T1D. **Results:** The average (standard deviation [SD]) glycated hemoglobin of respondents with a learner's or a driver's license was 9.0% (SD, 1.9%) and 8.9% (SD, 1.9%), respectively ($p=0.91$). The proportions of adolescents with a learner's or a driver's license who almost always or always checked their blood glucose prior to driving was 69% and 41%, respectively ($p=0.01$). Eighteen percent of adolescents with a learner's license and 41% with a driver's license experienced hypoglycemia while driving. The average number of weekly hypoglycemic events in each group was 2.0 (SD, 1.4) and 2.3 (SD, 2.0), respectively. There was a higher reported frequency of weekly mild hypoglycemic events between drivers who reported pulling over at least once while driving due to symptoms of hypoglycemia (3.25 ± 2.38) and those who reported never having pulled over for hypoglycemia (1.87 ± 1.31) ($p=0.012$). Respondents with a learner's license reported higher adherence to guidelines than those with a full license.

Conclusions: Clinical education needs to reinforce adherence to recommendations, particularly checking blood glucose or wearing a continuous glucose monitor prior to driving, for all adolescents of driving age. The frequency of mild hypoglycemic events per week is associated with self-reported hypoglycemic events while driving.

© 2019 Canadian Diabetes Association.

R É S U M É

Objectifs : Le présent travail avait pour but d'effectuer un sondage auprès des adolescents atteints du diabète de type 1 (DT1) qui ont l'âge légal pour conduire sur leur compréhension des risques associés à la conduite lors de diabète et leur adhésion aux recommandations.

Méthodes : La présente étude était une enquête transversale menée auprès de 191 adolescents, de 14 à 18 ans, atteints de DT1.

* Address for correspondence: Danièle Pacaud MD, Division of Pediatric Endocrinology, Alberta Children's Hospital, 2888 Shaganappi Trail, Calgary, Alberta T3B 6A8, Canada.

E-mail address: daniele.pacaud@albertahealthservices.ca

1499-2671/© 2019 Canadian Diabetes Association.

The Canadian Diabetes Association is the registered owner of the name Diabetes Canada.

<https://doi.org/10.1016/j.cjcd.2019.06.001>

Résultats : L'hémoglobine glyquée moyenne (écart type [ÉT]) des répondants qui détenaient un permis d'apprenti conducteur ou de conducteur était respectivement de 9,0 % (ÉT, 1,9 %) et de 8,9 % (ÉT, 1,9 %) ($p = 0,91$). Les pourcentages d'adolescents détenant un permis d'apprenti conducteur ou de conducteur qui surveillaient presque toujours ou toujours leur glycémie avant de conduire étaient respectivement de 69 % et de 41 % ($p = 0,01$). Dix-huit pour cent des adolescents qui détenaient un permis d'apprenti conducteur et 41 % des adolescents qui détenaient un permis de conducteur ont subi une hypoglycémie pendant la conduite. Le nombre moyen hebdomadaire d'épisodes d'hypoglycémie dans chaque groupe était respectivement de 2,0 (ÉT, 1,4) et de 2,3 (ÉT, 2,0). La fréquence hebdomadaire d'épisodes d'hypoglycémie légère a été plus grande chez les conducteurs qui déclaraient avoir eu à se ranger au moins une fois pendant qu'ils conduisaient en raison de symptômes d'hypoglycémie ($3,25 \pm 2,38$) que chez ceux qui déclaraient ne jamais avoir eu à se ranger en raison de l'hypoglycémie ($1,87 \pm 1,31$) ($p = 0,012$). Les répondants qui détenaient un permis d'apprenti conducteur ont déclaré une meilleure adhésion aux lignes directrices que ceux qui détenaient un permis de conduire.

Conclusions : L'enseignement clinique de tous les adolescents en âge de conduire doit permettre de renforcer l'adhésion aux recommandations, notamment la surveillance de la glycémie ou le port d'un lecteur de glycémie en continu avant de conduire. La fréquence hebdomadaire des épisodes d'hypoglycémie légère est associée à l'occurrence d'épisodes d'hypoglycémie pendant la conduite automobile auto-déclarés.

© 2019 Canadian Diabetes Association.

Introduction

Learning to drive is an important adolescent milestone that fosters independence and autonomy. Nonetheless, adolescent drivers are considered to be at high risk of motor vehicle collisions (MVCs) (1). According to Statistics Canada (2014), drivers 15 to 34 years of age account for 39.8% of MVC-related serious injuries and 36.1% MVC-related mortalities (2). Adult drivers with type 1 diabetes mellitus (T1D) are up to 180% more likely to be involved in an MVC (3,4), and those with T1D between 17 and 44 years of age are significantly more likely to be involved in an MVC than adults >44 years of age (4).

Hypoglycemia is a common occurrence in insulin therapy used in the management of T1D. Hypoglycemia affects cognitive function, including deficits in attention, impairment of memory and poor psychomotor function (5). In a 30-year follow-up study of participants of the Diabetes Control and Complications Trial/Epidemiology of Diabetes Interventions and Complications studies, half of the MVCs in which participants were involved as drivers were associated with significant hypoglycemic events (6). Thus, in theory, adolescents with T1D face challenges with hypoglycemia that pose a further risk to safety on the road.

Although diabetes mellitus must be declared when registering for a license, current Canadian legislation does not impose restrictions on drivers with diabetes who possess noncommercial driving licenses. To minimize the risk of hypoglycemia while driving, Diabetes Canada recently released updated guidelines for determining fitness to drive and glucose control protocols for individuals with T1D (7). Current recommendations suggest using a regularly calibrated blood glucose meter to monitor blood glucose or to wear a continuous glucose-monitoring device, keeping an accurate daily log of blood glucose measurements and having optimal blood glucose control.

To minimize hypoglycemia while driving, the Diabetes Canada guidelines recommend that glucose should be checked immediately prior to driving and every 4 h while driving using a capillary blood glucose monitor or continuous glucose-monitoring device. Drivers with a history of frequent mild hypoglycemia, severe hypoglycemic events with confusion or decreased level of consciousness, or hypoglycemia unawareness are advised to check their glucose levels more frequently (7). If a person senses that they are hypoglycemic while driving, they should pull over and not resume driving until an episode has been treated. If a driver has a blood glucose of <4 mmol/L prior to or while driving, they should ingest a rapid carbohydrate source, postpone driving for at least 40 min and should not drive until their blood glucose is >5 mmol/L (7).

If a driver has a blood glucose between 4 and 5 mmol/L, they should ingest rapid carbohydrates, postpone driving for 15 min and ensure that their blood glucose is >5 mmol/L prior to driving.

The aim of the current study was to assess the extent to which adolescents with T1D followed at the Alberta Children's Hospital (ACH) in Calgary, Alberta, Canada, understand the risks of driving with diabetes and how well they report adhering to recommendations for driving with diabetes. A secondary objective was to determine whether clinical measures can identify those adolescents who are at higher risk of adverse driving events. The results address an absence in the literature regarding of driving knowledge recommendations for youth with T1D.

Methods

Survey development and administration

This study was a cross-sectional survey of adolescents with T1D being followed in a tertiary care pediatric diabetes clinic.

Participants were recruited from the ACH diabetes clinic from July to December 2015. Adolescents were included if they were between 14 and 18 years old and were being followed up at the ACH pediatric diabetes clinic. This age group was chosen based on the lower age limit needed to obtain a learner driver's license in Alberta of 14 years, and the transition age limit set at 18 years of age by the ACH clinic. Exclusion criteria were: an intellectual disability that precluded the capacity to understand and complete the survey, and any language barriers that could limit understanding of the survey questions.

Consent was obtained from all participants. The study was approved by the Conjoint Health Research Ethics Board at the University of Calgary.

The survey was designed using questions adapted from the Canadian Diabetes Association 2003 driving guidelines (those that were available at the time of the design of the survey) (8), from Cox et al (9) and from local expert content. The survey divided respondents according to their driving level: no driving, learner's license or full driver's license. Survey questions assessed knowledge of recommendations for driving with diabetes, personal adherence to these recommendations and whether an individual had pulled over due to hypoglycemia. The initial version of the survey was reviewed by pediatric endocrinologists and diabetes educators working at the ACH diabetes clinic for content validity, and piloted on adolescent volunteers with and without diabetes to assess for flow and reading level as well as time needed to complete the survey. Responses to knowledge and practice questions were

summarized into knowledge scores and practice scores for each participant, with 1 point allocated to each response corresponding to Diabetes Canada recommendations for driving with diabetes. The maximum knowledge score was 11 and the maximum practice score was 7. The survey is presented in [Supplementary Appendix 1](#).

The surveys were completed by participants on a touch-screen tablet computer in a confidential clinic room setting without the presence of their family or usual health-care providers. A research assistant was present to answer any questions and provide instructions on how to complete the survey.

Chart review

A retrospective chart review was completed by an independent research assistant who was unaware of each participant's survey answers. Charts were reviewed for clinical data such as: glycated hemoglobin (A1C); frequency of mild hypoglycemic events per week; prior episodes of diabetic ketoacidosis (DKA); and prior episodes of severe hypoglycemic events, including hypoglycemic seizures.

Statistical analysis

For comparison purposes, respondents were grouped according to their driving level: no driving, learner's license or full driver's license. Data are presented as proportion (%) with confidence interval or as mean with standard deviation (SD). The difference in proportions was assessed using a chi-square test or Fisher exact test, as appropriate. The McNemar–Bowker test was used for paired analysis. The Mann–Whitney *U* test was used for independent-sample analysis. $p < 0.05$ was considered statistically significant.

Results

Participants

Of the 193 adolescents who were approached for study participation, 2 did not meet the inclusion criteria due to age < 14 years. The 191 youth who met the inclusion criteria participated in the analysis. Forty-nine percent were female. The average age was 16.1 (SD, 1.2) years and the average duration of diabetes was 6.8 (SD, 4.0) years. The average A1C was 9.0% (2.0%). The mean number of mild hypoglycemic events reported per week was 2.2 (2.2).

Fifty-three percent of respondents (102 of 191) did not have any class of driver's license. Thirty percent (57 of 191) had a learner's license and 17% (32 of 191) had a driver's license. The average age of those without a license was 15.6 (SD, 1.2) years, with a learner's license was 16.1 (SD, 1.0) years and with a driver's license was 17.3 (SD, 0.7) years.

Diabetes-specific risk factors were analyzed for participants with a license. The average A1C of those with a learner's or a driver's license was 9.0% (SD, 1.9%) and 8.9% (SD, 1.9%), respectively ($p = 0.58$). The average number of weekly hypoglycemic events for those with a learner's or a driver's license was 2.0 (SD, 1.4) and 2.3 (SD, 2.0), respectively ($p = 0.63$). Among respondents with a learner's license, 46% (26 of 57) always sensed hypoglycemia, 51% (29 of 57) almost always sensed hypoglycemia and 3% (2 of 57) sensed hypoglycemia most of the time. In respondents with a driver's license, 56% (18 of 32) always sensed hypoglycemia, 38% (12 of 32) almost always sensed hypoglycemia and 6% (2 of 32) sensed hypoglycemia most of the time. Two individuals with a learner's license experienced a hypoglycemic seizure in the previous year, whereas those with a driver's license had no seizure events. The proportion of respondents with a learner's or a driver's license who had been admitted to hospital with DKA (with the

exception of DKA at initial diagnosis of diabetes) in the last year was 9% (5 of 57) and 12.5% (4 of 32), respectively.

Knowledge of driving guidelines for adolescents with type 1 diabetes

The majority of respondents (99%) were aware that they should check their glucose level prior to driving. All respondents were aware that they required a driver's license in the car. The proportions among those who were aware of the recommendations to keep the following items in the car were as follows: glucometer, 99%; source of fast-acting carbohydrate, 98%; and insulin, 97%. Ninety-eight percent knew they should have a medical alert on their person.

Forty percent of respondents answered that they should treat a blood glucose < 4 mmol/L prior to driving and another 45% thought they should treat a blood glucose < 5 mmol/L. A comparison of blood glucose levels at which respondents with learner's and driver's licenses responded that they "should treat below" is shown in [Figure 1A](#). A similar comparison of blood glucose levels at which respondents reported "actually treating below" is shown in [Figure 1B](#). Seven percent of respondents were aware that they should wait 45 min after treating hypoglycemia prior to driving (based on the 2003 guidelines available at the time of this survey [8]). A comparison of the times between those with a learner's or a driver's license who reported they "should wait" prior to driving after treating hypoglycemia is shown in [Figure 2A](#). A similar comparison of the time they reported actually waiting is shown in [Figure 2B](#).

Practice of driving guidelines for adolescents with type 1 diabetes

[Figure 3](#) shows the frequency at which respondents with a learner's or driver's license checked their glucose level prior to driving. The proportions of those with a learner's or a driver's license who "almost always" or "always" checked their glucose level prior to driving were 69% and 41%, respectively ($p = 0.01$).

The proportions of adolescents with a learner's or a driver's license who "almost always" or "always" kept a glucometer in their car were 94% for those with a driver's license and 98% for those with a learner's license. The proportions of respondents with a learner's or a driver's license who "almost always" or "always" kept a source of fast-acting carbohydrate in the car were 96% and 100%, respectively. Forty-three percent of adolescents with a learner's license treated with carbohydrate prior to driving for all blood glucose values < 4 mmol/L, whereas 58% treated for all blood glucose values < 5 mmol/L. Forty-four percent of adolescents with a driver's license treated with carbohydrate prior to driving for all blood glucose values < 4 mmol/L, whereas 50% treated for all blood glucose values < 5 mmol/L.

The frequency with which respondents who reported that they would stop to test blood glucose if they felt hypoglycemic while driving is shown in [Figure 4](#). The proportions of those with a learner's or driver's license who "almost always" or "always" checked their blood glucose when sensing hypoglycemia while driving were 91% and 84%, respectively. The proportions of those with a learner's or a driver's license who "almost always" or "always" checked their glucose level after driving for 4 hours were 64% and 53%, respectively. There was no difference between license class and proportion of respondents who stated they would pull over on long trips to check for hypoglycemia ($p = 0.39$).

Reported hypoglycemia while driving

Eighteen percent of respondents with a learner's license compared with 41% with a driver's license had experienced hypoglycemia while driving. There was not a significant difference

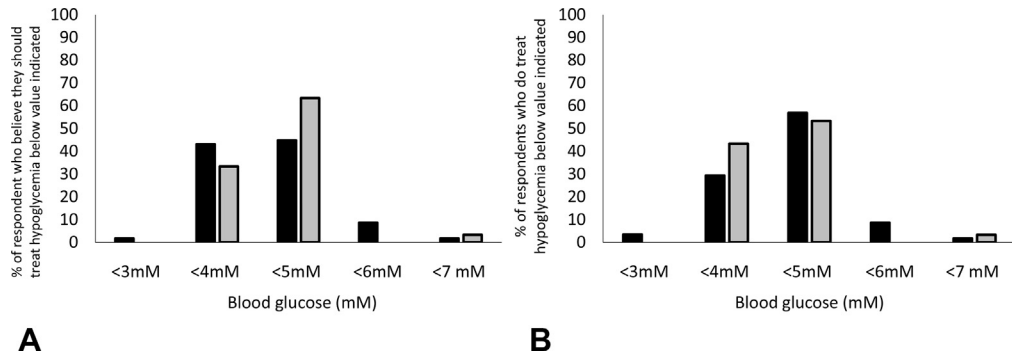


Figure 1. Blood glucose below which respondents believe that they should (A) and report that they do treat (B) with carbohydrates prior to driving. The number of respondents with a learner's license (black bars) was 57 and the number of respondents with a driver's license (grey bars) was 32. (A) There was no difference between the responses of learners and drivers (Fisher's Exact, $p=0.81$). (B) There was no difference between the responses of learners and drivers (Fisher's Exact, $p=0.59$). In a comparison of A and B, there was no significant difference between what an individual feels they should do and what they do in practice (McNemar-Bowker, $p=0.56$).

between license class and the proportion of respondents who pulled over while driving due to hypoglycemia ($p=0.78$). Of those with a learner's license who had experienced hypoglycemia while driving, 60% (6 of 10) had pulled over due to hypoglycemia. Forty-six percent (6 of 13) of those with a driver's license who had hypoglycemia while driving needed to pull over.

Diabetes-related factors as predictive measures of reported adherence to safety recommendations

There was a significant difference in the frequency of mild hypoglycemic events per week between those respondents who reported pulling over at least once while driving due to symptoms of hypoglycemia (3.25 ± 2.38) and those who reported never pulling over (1.87 ± 1.31) ($p=0.012$). There was no significant association between history of seizures in the past year ($p=1.00$) or ever ($p=0.59$), and with reports of pulling over at least once due to symptoms of hypoglycemia. None of the respondents with a full driver's license had a hypoglycemic seizure in the last year. There was no significant difference in A1C (8.90 ± 2.09 vs 8.96 ± 1.87 , $p=0.63$) in those with a license who had needed to pull over at least once due to hypoglycemia while driving relative to those who did not need to pull over.

Summary of knowledge and practice responses among those with a learner's or a driver's license

The median knowledge score was 9 for both respondents with a learner's license (95% confidence interval [CI], 8.21 to 8.68) and

those with a driver's license (95% CI, 8.37 to 8.94), with no significant difference ($p=0.43$). However, there was a significant difference between practice scores of respondents with a learner's license and a driver's license (learner's median: 5.0 [95% CI, 4.88 to 5.48]; driver's median: 5.0 [95% CI, 4.21 to 5.10]; $p=0.038$), indicating that those with a learner's license and those with a driver's license had similar knowledge of the driving guidelines. However, those with a learner's license reported better adherence to these guidelines. Scatterplots were produced to examine the relationship between knowledge scores and practice scores, but no linear relationship was evident.

Discussion

This is the first study of its kind to investigate knowledge and behaviours of adolescents with T1D on driving with diabetes. Forty-one percent of the current study respondents were aware they needed to check their glucose level prior to driving and were aware of the recommended items to keep in the car. The majority were also aware they need to treat a blood glucose <4 mmol/L prior to driving. Our study has highlighted, however, that clinical education needs to emphasize treating blood glucose levels between 4 and 5 mmol/L before driving. Although the new Diabetes Canada guidelines specify that individuals should wait 40 min after treating hypoglycemia prior to driving (7), the majority of adolescents in this study only waited 15 min. Adolescents were generally adherent with carrying diabetes supplies in their car and pulling over to check and treat a blood glucose of <4 mmol/L if they felt hypoglycemic while driving.

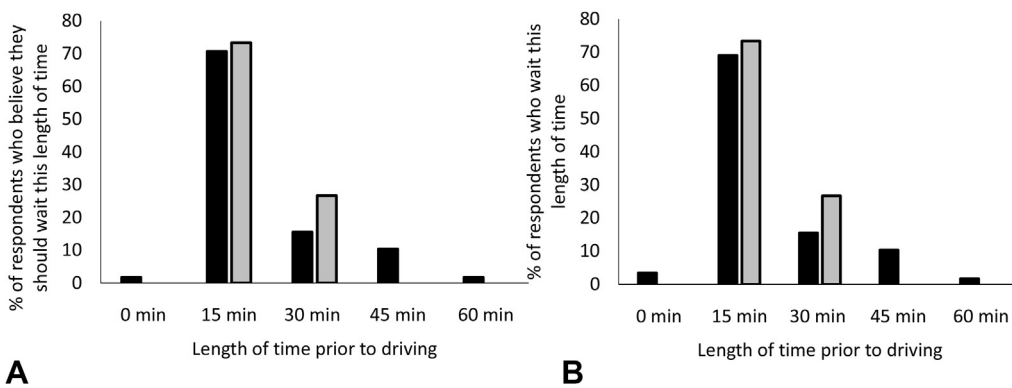


Figure 2. Length of time respondents believe that they should wait and length of time that respondents do wait before driving after treating hypoglycemia. The number of respondents with a learner's license (black bars) was 57 and the number of respondents with a driver's license (grey bars) was 32. (A) There was no difference between the responses of learners and drivers (Fisher's Exact, $p=0.12$). (B) There was a significant difference between the responses of learners and drivers (Fisher's Exact, $p=0.04$). In a comparison of A and B, there was no significant difference between what an individual feels they should do and what they do in practice (McNemar-Bowker, $p=0.53$).

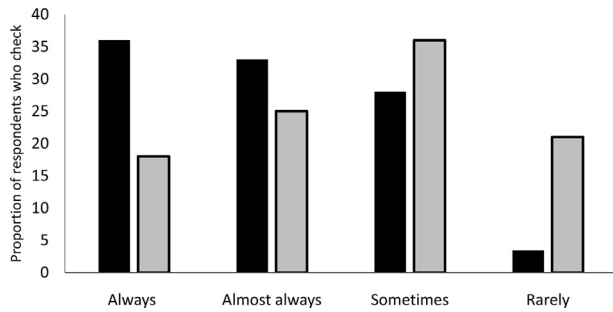


Figure 3. Frequency that respondents check their blood glucose prior to driving. The number of respondents with a learner's license (black bars) was 57 and the number of respondents with a driver's license (grey bars) was 32. There was a significant difference between license class and the reported frequency of checking for hypoglycemia prior to driving (Fisher's exact test, $p=0.01$).

Adolescents with a driver's license were less adherent to driving recommendations than those with a learner's license. In particular, those with a driver's license were less likely to check their glucose level prior to driving and less likely to pull their car over if they felt hypoglycemic. This reflects a change in behavioural practices between when a learner is driving with an adult and when adolescents with a driver's license assume sole responsibility. Graveling et al showed similar concerns with adherence in an adult population of individuals with T1D, where 59.9% of adults reported never testing glucose levels prior to driving and 38.1% did not have a glucometer in their vehicle while driving (10). A heavy emphasis on good driving practices in adolescence may translate into improved adherence in adulthood. This suggests a need for health-care team members to closely screen glucose log books, meter or continuous glucose-monitoring download reports when assessing for fitness to drive and to continue to emphasize the importance of following the Diabetes Canada recommendations (7) at each follow-up appointment. In the ACH clinic, it has been routine for many years to provide education to adolescents with diabetes at the driving age of 14 years (minimal age for a learner's license in Alberta). This is then repeated at least once before they transition to adult-care services. Education consists of reviewing the current Diabetes Canada guidelines. The clinic's electronic medical record has a section dedicated to documenting this type of education so that clinicians can see when it was completed. Automated reminders, not yet implemented, could provide a way to further ensure this occurs more frequently. Frequency of hypoglycemic events is discussed at each clinical encounter. Furthermore, at the time of assessment for medical fitness to drive by the ACH clinic, the adolescents are asked to sign a 1-page contract that reviews the need to assess glucose levels

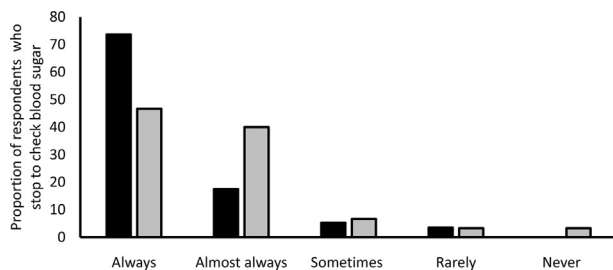


Figure 4. Frequency that respondents stop to check their blood glucose if they feel hypoglycemic while driving. The number of respondents with a learner's license (black bars) was 57 and the number of respondents with a driver's license (grey bars) was 32. There was no difference between license class and the proportion of respondents who check for hypoglycemia if they feel unwell while driving (Fisher's exact test, $p=0.06$).

before driving and the need to have glucose levels >5 mmol/L to ensure safe driving. Implementation of this contract was initiated after the current survey was completed. In the future, use of continuous glucose-monitoring devices and augmented pump therapy may also help ensure that glucose levels are monitored before each drive and that episodes of hypoglycemia while driving are limited.

In the current study, the frequency of reported hypoglycemia while driving was 18% for adolescents with a learner's license and 41% for those with a full license. Although those adolescents with a driver's license are less likely to check for hypoglycemia or to wait for the appropriate amount of time after treating hypoglycemia to resume driving, the difference in reported hypoglycemic events according to driving class likely also reflects that those with a driver's license have been driving for a greater length of time and are, therefore, more likely to have experienced an event of hypoglycemia during this activity.

In this study, we have addressed whether diabetes-related factors could determine if an adolescent would be more likely to experience hypoglycemia while driving. There was no difference in A1C levels between those who drove and those who did not or between adolescents with a learner's or a driver's license. There was no difference in episodes of DKA in the prior year between any of the groups. Adolescents who had more episodes of hypoglycemia per week tended to be more likely to have experienced hypoglycemia while driving. Similar findings have been reported previously by Cox et al in an adult population of individuals with T1D (11). In the Cox et al study, the degree to which an individual is affected by hypoglycemia and an individual's number of past hypoglycemia-related driving mishaps were independent predictors of future MVC (11). In the current study's population, there was no difference between the proportion of adolescents who had had severe hypoglycemic events or hypoglycemic seizures and those with a learner's or driver's license or without a license.

In adults with T1D, severe hypoglycemia is the strongest and most consistent variable that can predict MVCs (4). Simulation studies of induced hypoglycemia in adults with T1D demonstrated unsafe driving at blood glucose levels <3.8 mmol/L (12). The act of driving has been shown to cause hypoglycemia at a faster rate than resting activity due to increased metabolic demands and stress (12). Of concern, however, are the data showing that up to 25% of adult drivers with T1D may have difficulty sensing hypoglycemia (10). Both Diabetes Canada and the American Diabetes Association recommend enquiring routinely about loss of consciousness due to hypoglycemia, hypoglycemia requiring intervention by another person or that interfered with driving, hypoglycemia without warning and hypoglycemia unawareness to identify individuals at high risk for diabetes-related driving mishaps (7,13,14).

Few adolescents in the current study's population appeared to have severe hypoglycemic events or hypoglycemic seizures. This is consistent with the average A1C of 9% in this group, typical of the struggles that adolescents have in keeping A1C close to target values. The data suggest that, in the study's population with T1D, the most useful screening tool for an adolescent who is more likely to experience hypoglycemia-related morbidity while driving is the frequency of hypoglycemic events per week. In adolescents who reported >3 hypoglycemic events per week, a trial of continuous glucose monitoring could be considered to determine whether events typically occur in relation to driving and which insulin doses should be adjusted to minimize hypoglycemia. Interventions such as online learning modules on diabetes and driving safety precautions that have been shown to reduce hypoglycemia-related MVC in high-risk adults with T1D may be useful to reduce risk in adolescents of driving age who experience frequent or severe hypoglycemic events (11).

The primary limitations of this study are its survey-based nature and the number of available respondents who chose to take part. Focusing on the risk of hypoglycemia-induced MVCs rather than the reporting of actual events and reliance on respondents' recall may have led to under- or over-reporting. The frequency of mild and severe hypoglycemia was assessed through a chart review, which could also be affected by under-reporting of events by respondents and their families. The sequence of the survey questions, in which the knowledge questions were asked first, may have influenced how questions on practice were answered. Respondents may have wanted to provide researchers with a better answer than they practiced in reality. The results of the survey conducted in a university pediatric diabetes specialty clinic may not be generalizable to other populations of youth with diabetes.

Conclusions

Adolescents with T1D have excellent knowledge of recommendations for safe driving practices for individuals with diabetes but are less likely to implement these recommendations as they graduate to a full driver's license. Educational practices should emphasize the potentially severe consequences of hypoglycemia while driving, and regular review of barriers and challenges to adherence to safety practices should be incorporated into clinical practice. This should be done in all adolescents with T1D and especially in those with frequent mild hypoglycemia.

Supplementary Material

To access the supplementary material accompanying this article, visit the online version of the *Canadian Journal of Diabetes* at www.canadianjournalofdiabetes.com.

Acknowledgments

The authors are grateful for the participation of our adolescents with T1D and the support of the diabetes clinic at the Alberta Children's Hospital.

Author Disclosures

Conflicts of interest: None.

Author Contributions

K.P., H.V., D.P. and F.S. all contributed substantially to the conception and interpretation of the data for this study. K.P. and D.P. drafted the article. K.P., H.V., D.P., J.H.O., P.L., A.A. and F.S. critically appraised this article for important intellectual content. All authors approved the final version of the article before publication.

References

1. Romer D, Lee YC, McDonald CC, Winston FK. Adolescence, attention allocation, and driving safety. *J Adolesc Health* 2014;54(Suppl.):S6–15.
2. Transport Canada. Canadian motor vehicle traffic collision statistics 2014. https://www.tc.gc.ca/media/documents/roadsafety/cmvtcs2014_eng.pdf. Accessed August 26, 2019.
3. Orriols L, Avalos-Fernandez M, Moore N, et al. Long-term chronic diseases and crash responsibility: A record linkage study. *Accid Anal Prev* 2014;71:137–43.
4. Songer TJ, Dorsey RR. High risk characteristics for motor vehicle crashes in persons with diabetes by age. *Annu Proc Assoc Adv Automot Med* 2006;50:335–51.
5. Cox DJ, Gonder-Frederick LA, Kovatchev BP, Julian DM, Clarke WL. Progressive hypoglycemia's impact on driving simulation performance. Occurrence, awareness and correction. *Diabetes Care* 2000;23:163–70.
6. Gubitosi-Klug RA, Braffett BH, White NH, et al. The risk of severe hypoglycemia in type 1 diabetes over 30 years of follow-up in the DCCT/EDIC Study. *Diabetes Care* 2017;40:1010–6.
7. Diabetes Canada Clinical Practice Guidelines Expert Committee, Houlden RL, Berard L, Lakoff JM, Woo V, Yale JF. Diabetes and driving. *Can J Diabetes* 2018;42(Suppl. 1):S150–3.
8. Begg IS, Yale JF, Houlden RL, Rowe RC, McSherry J. Canadian Diabetes Association's clinical practice guidelines for diabetes and private and commercial driving. *Can J Diabetes* 2003;27:128–40.
9. Cox DJ, Gonder-Frederick LA, Shepard JA, Campbell LK, Vajda KA. Driving safety: Concerns and experiences of parents of adolescent drivers with type 1 diabetes. *Pediatr Diabetes* 2012;13:506–9.
10. Graveling AJ, Warren RE, Frier BM. Hypoglycaemia and driving in people with insulin-treated diabetes: Adherence to recommendations for avoidance. *Diabet Med* 2004;21:1014–9.
11. Cox DJ, Gonder-Frederick LA, Singh H, et al. Predicting and reducing driving mishaps among drivers with type 1 diabetes. *Diabetes Care* 2017;40:742–50.
12. Cox DJ, Gonder-Frederick LA, Kovatchev BP, Clarke WL. The metabolic demands of driving for drivers with type 1 diabetes mellitus. *Diabetes Metab Res Rev* 2002;18:381–5.
13. Lorber D, Anderson J, Arent S, et al. Diabetes and driving. *Diabetes Care* 2014;37(Suppl. 1):S97–103.
14. Houlden RL, Berard L, Cheng A, et al. Diabetes and driving: 2015 Canadian Diabetes Association updated recommendations for private and commercial drivers. *Can J Diabetes* 2015;39:347–53.

Supplementary Appendix Driving Survey Version 3

1. Date of survey _____
2. Initials _____
3. Date of birth _____
4. Do you have a learner's (Class 7) license? Yes/No
If no:
 - a. Have you taken the exam before? Yes/No
 - b. Do you plan to apply for a learner's license in the next year? Yes/No
5. Do you have a (click all that apply)?
 - a. Class 6 license (for motorcycles and mopeds).
 - b. Class 5 license (license for private vehicles, noncommercial).
 - c. Class 4 license (professional license for ambulances and taxis)
 - d. Class 3 (3-axle vehicles).
 - e. Class 2 (professional license—bus).
 - f. Class 1 (professional—all vehicles).
6. How often are you able to tell when you are having a low blood sugar?
 - a. Always.
 - b. Almost always.
 - c. Most of the time.
 - d. Often.
 - e. Rarely.
 - f. Never.
7. The following are questions about your current knowledge on recommendations for driving with type 1 diabetes:
 - a. Should you check your blood sugar before driving? Yes/No
 - b. When driving, which of the following items should you have in your car:
 - No specific items? Yes/No
 - Driver's license? Yes/No
 - Glucometer? Yes/No
 - Fast-acting carbohydrate for treatment of hypoglycemia? Yes/No
 - Insulin? Yes/No
 - c. Should you decide not to drive if:
 - Your blood glucose is too low or dropping rapidly? Yes/No
 - Your blood glucose is too high or rising rapidly? Yes/No
 - d. Should you drive if your blood glucose is:
 - Below 4? Yes/No
 - Below 5? Yes/No
 - Above 15? Yes/No
 - Above 15 with ketones? Yes/No
 - e. Below what blood glucose value should you treat with carbohydrates prior to driving?
(a) 3. (b) 4. (c) 5. (d) 6.
 - f. If you have a low blood sugar <4 mmol/L prior to driving, how long should you wait after consuming carbohydrates before driving?
(a) 15 min. (b) 30 min. (c) 45 min. (d) 60 min.
 - g. If you have a blood sugar between 4 and 5 mmol/L prior to driving, what should you do?
 - (a) Consume carbohydrate and then proceed with driving.
 - (b) Consume carbohydrate and then wait 15 min before driving.
 - (c) Consume carbohydrate and then wait 30 min before driving.
 - (d) Consume carbohydrate and then wait 45 min before driving.
 - h. On long trips, how often should you pull over to check your blood glucose?
 - (a) No need to check. (b) Every 1 hour (h). (c) Every 2 h. (d) Every 3 h. (e) Every 4 h. (f) Every 5 h. (g) Every 6 h.
 - i. Should you stop and check your blood glucose if you feel unwell or low while driving? Yes/No
8. (To be answered by those who have a valid license including a learner's license.) The following are questions about your driving:
 - a. Do you check your blood sugar before driving?
(scale of 1 to 5: 1 = never, 2 = rarely, 3 = frequently, 4 = almost always, 5 = always).
 - b. Do you keep a blood glucose meter with you in your car?
(scale of 1 to 5: 1 = never, 2 = rarely, 3 = frequently, 4 = almost always, 5 = always).
 - c. Do you keep sources of fast-acting carbohydrates in your car?
(scale of 1 to 5: 1 = never, 2 = rarely, 3 = frequently, 4 = almost always, 5 = always).
 - d. Would you decide not to drive if:
 - Your blood glucose is too low? Yes/No
 - Your blood glucose is too high? Yes/No

- e. Do you drive if your blood glucose is:
Below 4? Yes/No
Below 5? Yes/No
Above 15? Yes/No
Above 15 with ketones? Yes/No
- f. Below what blood glucose value do you treat with carbohydrates prior to driving?
(a) 3. (b) 4. (c) 5. (d) 6.
- g. If you have a low blood sugar (below 4 mmol/L) prior to driving, how long do you wait before driving?
(a) 15 min. (b) 30 min. (c) 45 min. (d) 60 min.
- h. Do you check your blood glucose if you feel unwell or low while driving?
(scale of 1 to 5: 1 = never, 2 = rarely, 3 = frequently, 4 = almost always, 5 = always).
- i. Do you pull over on short trips to test your blood glucose?
(scale of 1 to 5: 1 = never, 2 = rarely, 3 = frequently, 4 = almost always, 5 = always).
- j. Do you pull over on long trips to test your blood glucose?
(scale of 1 to 5: 1 = never, 2 = rarely, 3 = frequently, 4 = almost always, 5 = always).
- k. Have you ever had a low blood sugar while driving? Yes/No
- l. How many times have you had a low blood glucose while driving? _____
- m. Have you ever had to pull over or stop the vehicle because your blood sugar became too low or started dropping rapidly? Yes/No
- n. Have you ever had to pull over or stop the vehicle because your blood sugar became too high? Yes/No
- o. Have you had any severe lows (needed help to treat) at any time since you started driving (not necessarily while driving)? Yes/No
- p. Have you had any major decreases in your HbA1c since you started driving? Yes/No
- q. Have you needed to stop driving because of low glucoses? Yes/No
- r. Have you ever had a ticket or fine for driving? Yes/No
If yes, why?: (a) Speed. (b) Reckless driving. (c) Parking. (d) Other.
- s. Have you ever had a motor vehicle collision? Yes/No
9. How worried are you about the impact of diabetes on your driving?
(scale of 1 to 5: 1 = not at all, 2 = a bit worried, 3 = somewhat worried, 4 = quite worried, 5 = very worried).
10. Have you ever received teaching in the diabetes clinic about driving with diabetes? Yes/No
11. Who in the diabetes clinic has discussed driving with you?: (please check all that apply)
- Medical doctor
 - Registered nurse
 - Dietician
 - Psychologist
 - Social worker
 - Other
 - No one