

## Characterizing social and policy determinants of hospital length of stay among paediatric inpatients with diabetes using linked population-based data

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### Abstract

#### Background

Evidence is limited on the non-medical factors influencing hospital length of stay (LOS) among paediatric inpatients with diabetes, notably potential social and policy correlates. This study aimed to characterize the associations of socioeconomic status and health policy environment with diabetes-attributable LOS to help inform accountability monitoring of a provincial comprehensive diabetes strategy aiming to minimize time in hospital among this high-risk population.

#### Data and methods

This retrospective population-based study drew on multiple linked administrative and geospatial databases among all children aged 18 and under with a diabetes-related hospitalization in the province of New Brunswick, Canada, during the four-year period following implementation of an insulin pump funding program. Multiple linear regression was used to assess the role of access to the public insulin pump resourcing scheme and relative neighbourhood deprivation as predictors of days spent in acute care, controlling for age, sex, and place of residence.

#### Results

Among the paediatric inpatient population ( $N = 386$ ), 21% had accessed social resources made available through the insulin pump funding policy and 42% resided in the most materially deprived neighbourhoods. Diabetes-related hospital stays averaged 3.87 days. Paediatric inpatients having accessed resources through the social insurance policy spent significantly fewer days in hospital (1.34 days less [95% CI: 0.63–2.05]) than those who had not, all else being equal. Observed differences in LOS by neighbourhood socioeconomic deprivation were not found to be statistically significant in the multivariate analysis.

#### Conclusion

Findings from this context of universal medical coverage suggested that public policy for supplemental financing of assistive technologies among children with diabetes may be associated with reduced burden to the hospital system. The causes of socioenvironmental disparities in LOS require further investigation to inform interventions to mitigate preventable patient-level variations in hospital-based health outcomes.

#### Keywords

hospitalization days; diabetes complications; insulin infusion systems; public financing; routinely collected health data; hospital discharge survey; data linkage

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## Introduction

Type 1 diabetes mellitus (T1D), a chronic endocrine disorder most often diagnosed in childhood or adolescence, is primarily managed at the individual, family, and community levels but has important implications for the hospital system [1–4]. In the absence of a known cure, therapeutic options include multiple daily injections of insulin or continuous subcutaneous insulin infusion using insulin pumps. Suboptimal management of T1D may increase the burden on acute hospitals due to diabetic ketoacidosis (DKA) and other complications, the risks of which may be exacerbated by socioeconomic conditions and healthcare funding resources [1, 2, 5]. Advances in diabetes-related technologies such as insulin infusion pumps can help improve health outcomes among children and adolescents living with T1D [3, 6–9], although they tend to incur significantly higher costs [10]. Disparities in access to insulin pumps persist within and across countries owing to differences in clinical practices as well as economic reasons, including inadequacy of reimbursement of these devices by public health systems and private insurance [3, 11]; such disparities have been found even in countries of universal medical coverage such as Canada, France, and New Zealand [12–14]. Yet, despite evidence that paediatric patients with T1D tend to stay in hospital longer than those without diabetes, the literature is limited on diabetes-specific hospitalization patterns among children [2]. Hospital length of stay (LOS) is considered a salient metric of health system costs and performance and may indicate different medical and non-medical factors, such as hospital characteristics, severity of complications, and continuity of care; however, research on social determinants of LOS is fragmented and incomplete [15–17].

Data limitations often preclude characterizing the broader social and policy context that may influence length of stay. The complexity of factors directly or indirectly related to LOS means much remains unknown [15]. Studies aiming to understand patient-level variations in LOS using routinely collected hospital administrative data tend to be limited to factors such as age, sex, diagnostic group, admission type, and source of insurance [18, 19]. Innovations in data linkages are facilitating population-based studies of the social correlates of cause-specific hospital stays [20]. In Canada, one study using linked data indicated that LOS among adult inpatients with chronic conditions was not associated with perceived unmet healthcare needs [21]. Other research found the risk of acute-care admissions was higher among children with diabetes of lower socioeconomic status [13]. We are unaware of any studies in Canada or elsewhere investigating associations of social environments, including public funding policies for insulin pumps, with LOS among paediatric inpatients with diabetes.

Echoing global epidemiological trends of rising prevalence of paediatric diabetes [4], the Canadian province of New Brunswick has seen its paediatric diabetes rate increasing over time: from 2.8 per thousand in 2000 to 4.2 per thousand in 2016 [22]. To address the escalating burden, the provincial government adopted a comprehensive diabetes strategy in 2011 which identified among its goals improving affordable access to insulin pumps and, ultimately, reducing hospital days by persons with diabetes [23]. However, the strategy document was silent on measures or information needs on

the social determinants of diabetes and related health system outcomes [24]. To better inform policy and planning options aimed at minimizing time in hospital among the high-risk paediatric population, the objective of this research was to assess the associations of socioeconomic status and a public insulin pump funding policy with diabetes-related LOS among paediatric inpatients. A retrospective population-wide study design was used, drawing on linked administrative and socioenvironmental datasets covering all paediatric inpatients with diabetes in the province of New Brunswick, Canada.

## Materials and methods

### Study setting

Relative to other Canadian provinces, New Brunswick is less populous (2.1% of the national population), more rural (37.4% reside outside a large population centre compared with the national rate of 16.8%), and of lower economic wellbeing (22.2% of children live below the low-income measure compared with 17.0% nationally) [25]. Three-quarters (74.2%) of the population are concentrated in the three southernmost of the province's seven health zones (Moncton, Saint John, and Fredericton areas) [25].

As in all the country's provinces and territories, New Brunswick's publicly funded health system (known as NB Medicare) covers all essential physician and hospital services. However, pharmaceuticals are inconsistently covered across Canadian jurisdictions through public insurance, in turn resulting in inter-provincial variations in completeness of drug information systems [26]. Coverage of diabetes devices and supplies also ranges across the country and has evolved over time [27]. Different funding schemes for insulin pump therapy have emerged in recent years across provinces, with varying age limits and other eligibility criteria [1]. In New Brunswick, the provincial Insulin Pump Program (NB-IPP) was introduced in 2012 to cover patients aged 18 years and under who are medically eligible for pump therapy; six years later the age limit was increased to 25 years. The social insurance policy was adopted to help offset the costs of the equipment and supplies obtained from provincially approved vendors on a sliding scale, with families responsible for part of the financial contribution depending on income. Supplementary pump costs may be covered through private health insurance; some private carriers may require proof of prior application to the public program. The NB-IPP does not cover the costs of insulin. All recipients of program support are required to renew their participation periodically.

The result of a government-academic collaboration, the launch of the New Brunswick Institute for Research, Data and Training (NB-IRD) in 2015 allowed for the availability of multiple linkable administrative datasets for research purposes from different government departments and public bodies [28, 29]. At the time of the present analysis, linkable health administrative datasets were available capturing de-identified information on residents eligible for NB Medicare, hospital discharge abstracts, and NB-IPP applications and claims. Additional geocoded socioenvironmental datasets were made available to the linkable data platform through the

Canadian Urban Environmental Health Research Consortium (CANUE) [30].

## Data sources and study population

This study included information on all paediatric inpatients with diabetes over a four-year period following implementation of the NB-IPP (fiscal years 2012/13 to 2015/16). Four deidentified datasets of administrative and geospatial information were linked deterministically: three person-level datasets on resident registrations, acute-care hospitalizations, and NB-IPP enrolments, plus a fourth geocoded dataset on socioeconomic deprivation. The person-level administrative datasets were linked by (scrambled) personal health numbers, which were then linked with the socioenvironmental information by residential postal code.

The registration data were used to distinguish all residents aged 18 and under eligible for NB Medicare. Persons having out-migrated from the province during the observation period were omitted from the analysis. Some groups are excluded from NB Medicare coverage owing to their participation in federal health programs; this number represents less than 3% of the population and is largely limited to adults (e.g., members of the Canadian Forces, federal penitentiary inmates).

The provincial Discharge Abstract Database (DAD), which captures standardized administrative and clinical information on all hospitalizations, was used to delineate the study population (paediatric inpatients). Given universal coverage of hospital services, the data are considered complete recordings of inpatient stays across the province's 21 acute-care facilities. In the absence of a children's hospital in New Brunswick, some paediatric patients with complex conditions may have received care at specialized centres outside the province, notably in neighbouring Nova Scotia or Quebec; these data are excluded from the present analysis. Four years of inpatient data were pooled together to obtain sufficient sample sizes for analysis. Diabetes-related admissions were ascertained based on the primary diagnostic reason for the length of stay as mapped to the International Classification of Diseases, Tenth Revision (ICD-10-CA codes E10-E14) [31]. While the administrative codes include hospitalizations for both types 1 and 2 diabetes, cases among paediatric patients chiefly reflect T1D admissions. An evaluation of a provincial DAD elsewhere reported high validity of diabetes coding (sensitivity of 81.5–92.1%, specificity of 93.9–97.0%) [32].

## Hospital length of stay

As the outcome of interest, LOS was measured for each paediatric inpatient by the number of days between admission and discharge, collated in the DAD according to fiscal year of discharge.

## Health policy and socioenvironmental correlates

To compare the characteristics of those who accessed public insulin pump resourcing versus those who did not, enrolment histories were captured from the NB-IPP database. The data included patients' basic demographics, program eligibility,

family financial contributions, and parental consent for sharing details regarding program participation; some administrative information, such as the device requested and the referring physician, were not identifiable in the dataset made available for research purposes [33]. Following research approaches elsewhere [13], individuals were identified here by whether they had at least one funding application within the four-year period following program implementation. The data were censored for those who surpassed their 19th birthday.

We further considered patients' social and material conditions as a potential determinant of length of stay. Since the administrative health datasets lack information on individuals' socioeconomic position, geospatial measures of relative deprivation were used through data linkage by annual residential postal code with the Canadian Marginalization Index (CAN-Marg), a set of census-based measures enabling identification of vulnerable population groups [30, 34]. The CAN-Marg is often ordered in the health research literature by quintiles according to increasing neighbourhood marginalization; however, given the small numbers of paediatric admissions in this study, three categories were distinguished: those living in the two least deprived quintiles, those in the third or fourth quintiles, and those in most deprived quintile.

Also considered as potential confounders were the patient's age, sex, and health zone of residence, as obtained from the resident registration database. In the Canadian context, health zones refer to administrative areas defined by provincial health ministries for purposes of services planning and delivery.

## Analytical techniques

This study conforms to the RECORD (REporting of studies Conducted using Observational Routinely-collected health Data) protocol [35]. Descriptive, bivariate, and multiple regression analyses were conducted for exploring the outcome of interest and its associations with the key hypothesized social, demographic, and policy variables. The Student *t*-test was used for the bivariate analysis. For the multivariate analysis, in addition to hospital stays for all types of diabetes complications, we also looked at correlates of LOS for DKA-specific stays. Following research elsewhere [16], linear regression was used. Confidence intervals (CIs) were set at 95% ( $\alpha = 0.05$ ). The analyses were performed using SPSS v25 statistical software.

## Research ethics and data availability

The study was approved by the University of New Brunswick's Research Ethics Board, for compliance with ethics protocols for conducting secondary analyses using linked administrative data accessed through the NB-IRDT (REB #2017-076). The provincial administrative health datasets are not readily available because restrictions apply to the accessibility of these confidential data, which were used under license for the current study. Requests to access the datasets for research purposes should be directed to the NB-IRDT ([www.unb.ca/nbirdt](http://www.unb.ca/nbirdt)). Requests for accessing the geographic socioenvironmental datasets may be directed to CANUE ([www.canue.ca](http://www.canue.ca)).

## Results

The dataset linkages yielded an initial paediatric inpatient population of 392 diabetes-related hospitalizations among 279 individuals over the four-year period. Excluding those lacking a valid residential postal code history in New Brunswick or neighbourhood deprivation information (~1% of the records), the final analysis included 386 acute-care hospital stays (~0.5% entailing transfers). Based on provincial estimates of diabetes prevalence among children and adolescents [22], this translated to approximately 15.1 hospitalizations per 100 person-years in the paediatric population living with diabetes. The great majority (90.6%) of inpatient stays recorded T1D as the primary diagnosis, with the balance divided evenly between type 2 diabetes (4.7) and other or unspecified types (4.7%).

Among these paediatric inpatients, one-fifth (21%) had accessed the NB-IPP (Table 1). Drawing on nationally defined socioeconomic distribution indices, approximately one-fifth (20%) resided in the least materially deprived neighbourhoods (quintiles 1 and 2) and two-fifths (42%) resided in the most deprived neighbourhoods (quintile 5). There were somewhat more female inpatients (56%) than males (44%).

Hospital episodes due to paediatric diabetes averaged 3.87 days, with no discernible year-over-year pattern across the period of observation (Figure 1). The bivariate analysis revealed that the mean LOS was significantly lower among those having accessed the NB-IPP compared with those who had not: 3.25 days versus 4.03 days ( $p < 0.05$ ). Stays were somewhat shorter among those living in less deprived neighbourhoods (quintiles 1-4: 3.68 days) versus those in the most deprived neighbourhoods (quintile 5: 4.13 days), as well as among males (3.74 days) versus females (3.97 days), but the observed differences were not statistically significant.

According to results from the multiple regression (Table 2), paediatric inpatients who had accessed the NB-IPP experienced significantly shorter diabetes-related stays, on average 1.34 days less (95% CI: 0.63–2.05 days less), compared with those who did not access the social policy scheme, after controlling for other sociodemographic characteristics. Those in the oldest paediatric age group (15–18 years) experienced significantly shorter stays compared with the youngest (0–9 years). Some differences were observed by health region, with inpatients residing in Zone 2 (Saint John area) or Zone 3 (Fredericton area) having a shorter average LOS compared with those residing in Zone 1 (Moncton area). Neither the patient's sex nor their residential neighbourhood deprivation index showed statistically significant differences in terms of time spent in hospital, all else being equal.

With regard to DKA-specific stays, which represented 40% of all diabetes-related stays, the LOS averaged 3.16 days. Patients who had accessed the NB-IPP averaged 1.51 fewer days in acute care (95% CI: 0.38–2.63 fewer days), compared with those who did not access the social policy scheme, adjusting for other socioenvironmental and demographic variables (Table 2, model 2).

## Discussion

Using population-representative data from multiple linked administrative and geospatial databases, this study represents

the first exploration of social and policy correlates of hospital length of stay among paediatric inpatients with diabetes in the province of New Brunswick, Canada. We found paediatric inpatients who had accessed public resources made available through a new provincial insulin pump funding policy experienced significantly shorter diabetes-related stays compared with those who had not accessed the policy scheme, with a mean LOS of 1.34 fewer days (95% CI: 0.63–2.05 fewer days), after controlling for other demographic and socioenvironmental characteristics. A similar association held for DKA-specific hospitalizations, with the LOS averaging 1.51 days less (95% CI: 0.38–2.63 days less).

The findings suggest that, regardless of universal coverage for essential medical and hospital services, given the self-care skills and high out-of-pocket expenses required to manage diabetes, the health financing policy context influences health outcomes [1, 36]. Public resourcing may offer expanded opportunities for purchasing healthy foods, engaging in physical activities, and other lifestyle modifications which may shape health capabilities and, in turn, diabetes outcomes including preventable complications [36]. Enhanced health capabilities and, in particular, health literacy to address parental anxiety may help reduce hospital utilization among paediatric inpatients [37].

The results aligned with investigations of a social policy for funding of assistive devices in the Canadian province of Ontario, which suggested reasons to support public funding of paediatric insulin pumps based on favourable safety profiles and clinical perceptions of the need to reduce disparities in social support systems for children and youth living with T1D [13, 38].

Similarly to a study from New Zealand [14], significant (but unexplained) regional differences were found in population-based outcomes despite the public funding of insulin pumps. Further research is needed to better understand the clinical practices, referral patterns, support systems, or other patient characteristics that may drive such regional disparities. On the other hand, socioeconomic status, as measured through neighbourhood-level categorization of material deprivation, was not found here to be significantly associated with LOS. Only modest differences in LOS among low-income groups have been observed for other health interventions in the Canadian hospital system [20]. Moreover, a previous study from Toronto, Canada's largest city, found a non-linear socioeconomic gradient in health outcomes among paediatric patients living with T1D [5]. It is possible that, given New Brunswick's exclusively rural and small urban population, combined with the small number of paediatric hospitalizations ( $N = 386$ ), there lacked statistical power in terms of population size and heterogeneity across deprivation categories to independently account for area-based disparities beyond health zones.

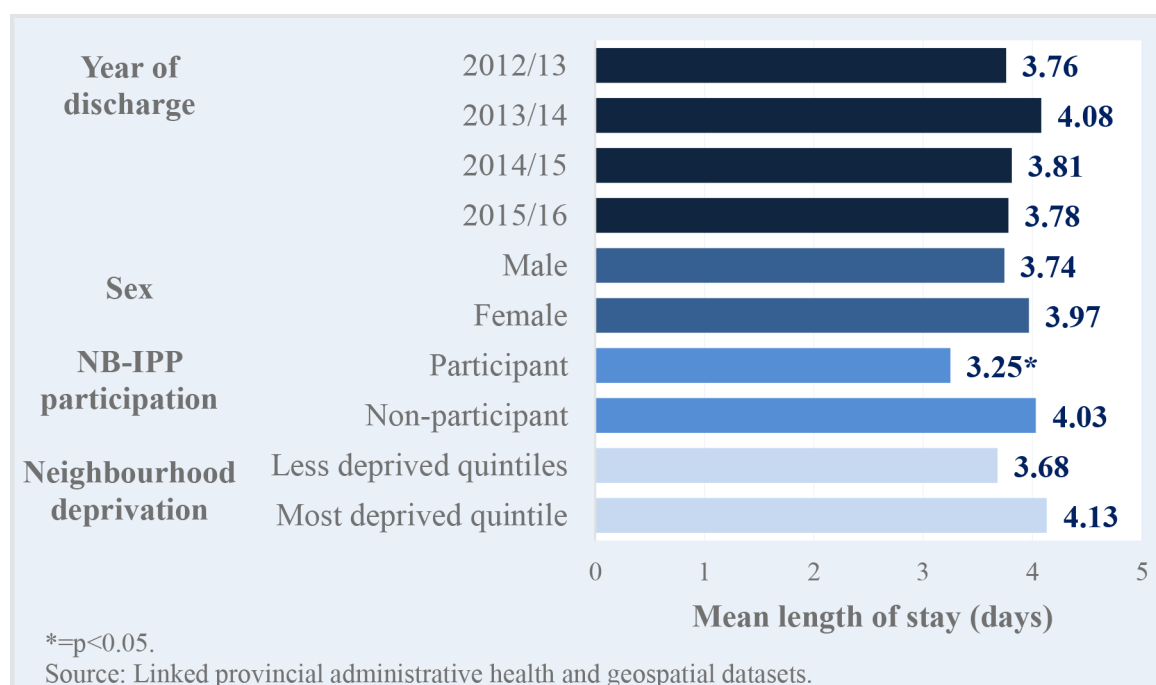
A key strength of this study was its population-wide design. Limitations included the lack of available information in the linkable data platform at the time of analysis on complete pharmaceutical records including insulin prescriptions, glycated hemoglobin levels upon hospital admission, diabetes duration among both NB-IPP participants and non-participants, actual pump utilization or discontinuation patterns, and other sources of financial support such as private insurance coverage. Also lacking from

Table 1: Sociodemographic distribution of the paediatric inpatient population with diabetes, New Brunswick (Canada), 2012/13 to 2015/16

Characteristic	Number (and percentage)
<b>Age</b>	
0–9 years	111 (29%)
10–14 years	152 (39%)
15–18 years	123 (32%)
<b>Sex</b>	
Male	171 (44%)
Female	215 (56%)
<b>Enrolment history in the NB Insulin Pump Program</b>	
Participant	81 (21%)
Non-participant	305 (79%)
<b>Neighbourhood deprivation index</b>	
Quintiles 1-2 (least deprived)	78 (20%)
Quintiles 3-4	147 (38%)
Quintile 5 (most deprived)	161 (42%)
<b>Health region of residence</b>	
Zone 1 (Moncton area)	99 (26%)
Zone 2 (Saint John area)	93 (24%)
Zone 3 (Fredericton area)	108 (28%)
Zones 4-7 (northern areas)	86 (22%)
<b>TOTAL</b>	<b>386 (100%)</b>

Source: Linked provincial administrative health and geospatial datasets.

Figure 1: Length of stay in acute care by selected sociodemographic and policy correlates among the paediatric inpatient population with diabetes



our analysis was information that could have offered a more thorough understanding of the facilitators and barriers to accessing the funding program at the patient and family level (such as parental education, ethnicity, and knowledge of official languages) and at the health system level (e.g.,

conformity with evidence-informed primary care management). It is possible that some children may have been diagnosed with diabetes upon hospitalization. The risk of selection bias is also possible, given that patients and their families eligible for program support must have already demonstrated

Table 2: Results from the linear regression analyses for predictors of length of stay (in days) among the paediatric inpatient population with diabetes, total and for diabetic ketoacidosis

	(1) All diabetes-related stays (N = 386)			(2) Stays for diabetic ketoacidosis (N = 156)		
	B	95% confidence interval	p-value	B	95% confidence interval	p-value
<b>Age</b> (ref: 0-9 years)						
10-14 years	0.28	-0.41-0.98	0.43	-0.05	-1.38-1.28	0.94
15-18 years	-1.04*	-1.77--0.31	0.01	-1.48*	2.75--0.22	0.02
<b>Sex</b> (ref: Male)						
Female	0.28	-0.29-0.85	0.34	0.46	-0.46-1.39	0.32
<b>NB-IPP participation</b> (ref: Non-participant)						
Participant	-1.34*	-2.05--0.63	0.00	-1.51*	-2.63--0.38	0.01
<b>Neighbourhood deprivation</b> (ref: Quintiles 1-2)						
Quintiles 3-4	0.28	-0.52-1.07	0.49	0.72	-0.58-2.02	0.28
Quintile 5: most deprived	0.41	-0.43-1.24	0.34	0.76	-0.68-2.21	0.30
<b>Health region</b> (ref: Zone 1: Moncton area)						
Zone 2: Saint John area	-2.24*	-3.07--1.41	0.00	-2.58*	-3.99--1.17	0.00
Zone 3: Fredericton area	-1.45*	2.23--0.67	0.00	-1.84*	-3.10--0.58	0.01
Zones 4-7: northern areas	0.47	-0.42-1.36	0.30	0.23	-1.41-1.88	0.78

Note: \* =  $p < 0.05$ ; ref = reference group; NB-IPP = New Brunswick Insulin Pump Program.

Source: Linked provincial administrative health and geospatial datasets, 2012/13-2015/16.

regular follow-up with a diabetes healthcare team, which may thus affect the statistical results [39]. More generally, given the well-known lags between administrative data capture and data readiness for research use [40], compounded by the substantial resource demands of building linkable data platforms in smaller jurisdictions such as New Brunswick [28], this analysis was limited to the four-year period following NB-IPP implementation. As such, we were presently unable to track effects of the subsequent change in program age limit or of transition experiences from paediatric to adult care, when care disruptions may lead to increases in adverse health outcomes [41].

## Conclusions

This novel characterization of social and policy correlates differentiating lengths of hospital stay among paediatric inpatients with diabetes highlighted that the health policy environment, specifically, access to a universal insulin pump funding scheme, was associated with significantly shorter stays. Results were suggestive, albeit not inferring causality, of positive returns to the hospital system of public policies for reducing the financial burden among families for diabetes-related technologies. Reliable estimates of the rate of insulin pump uptake among persons living with T1D are limited in Canada, as are evidences on whether government financing results in more equitable access to pumps [42]. More research is needed on cost-effectiveness of social policy initiatives to help inform decisions regarding equitable access and possible expansion of public funding for new assistive technologies for diabetes management among paediatric patients.

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## Competing interests

The authors declare they have no competing interests.

## Ethics statement

The study was approved by the University of New Brunswick's Research Ethics Board (REB #2017-076).

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## Abbreviations

CAN-Marg: Canadian Marginalization Index  
CANUE: Canadian Urban Environmental Health  
Research Consortium  
CI: confidence interval  
DAD: Discharge Abstract Database  
DKA: diabetic ketoacidosis

LOS: length of stay  
NB-IPP: New Brunswick Insulin Pump Program  
NB-IRDT: New Brunswick Institute for Research,  
Data and Training  
T1D: type 1 diabetes

