

Age Affects the Impact of Important Predictors on Mental Health Emergency Department Visits

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Abstract

Visits to emergency departments (EDs) for pediatric mental health care have increased over the years. The likelihood of ED re-visit is greatest for older children; however, little is known about age-varying effects on ED visits/re-visits. This study used population-based administrative databases from Alberta, Canada, to investigate the association of predictors on mental health ED visit frequency by age for 27,947 children who presented at least once for mental health care from April 2002 to March 2011. A marginal regression model with age-varying effects for sex, geographic area, and socio-demographic group was fit. The impact of predictors depended on a child's age. Notably, older males had lower ED visit frequencies compared to females (age 15 adjusted hazard ratio [aHR] = 0.70, 95% confidence interval [CI] [0.65, 0.76]) than younger males (age 10 aHR = 1.83, 95% CI [1.50, 2.24]). Children with particular ages for some socio-demographic groups also showed higher ED frequencies than children from the non-subsidized group. The analysis revealed important age-varying effects on predictors of mental health ED visit frequency.

Introduction

Emergency department (ED) visits for pediatric mental health care in the United States (US) and Canada have increased considerably in the past decade.¹⁻³ In the United States, in particular, such visits

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have been considered the fastest growing type of visits to EDs.⁴ These visits are made by children and youth who may or may not have been previously diagnosed with a mental disorder or problem, and who are ill, injured, or experiencing a psychiatric crisis. Care provided in an ED can stabilize acute mental health problems and facilitate urgent follow-up for symptom management and family support.⁵ In both the US and Canada, pediatric mental health visits are estimated to now account for 1–3% of all ED visits by children.^{2, 6, 7} While the majority of these ED visits are single visits, up to 40% children and youth may re-visit the ED within a short period of time for additional support and care.⁸

The majority of studies on reasons and predictors of ED re-visits originate from the US. Such studies have shown that a child's racial and socio-economic statuses differentiate the frequency of ED visits for mental health care: White, non-Hispanic children visit the EDs in the United States more frequently for mental health care than for other medical emergencies.⁷ Black American children also have higher ED visit rates for mental health compared to white American children,¹ and mental health visit rates are higher for children aged 13–20 years compared to those who are 6–12 years of age.¹ Age, race, ethnicity, and sex have been shown to predict ED visits for pediatric mental health care in other studies.^{8–10} These studies do not allow for changes in these variables over time, and do not show the impact of these changes (age-varying effects) on ED visits and re-visit. The likelihood of ED re-visit for mental health care has been shown to increase with age,⁸ and that the time to ED return decreases with age.¹¹ Thus, statistical models that account for time-dependent regression coefficients, or age-varying coefficients, are ideal so that studies can use the age of the child to estimate dynamic relationships between predictors and outcomes over time.¹² Such an approach can provide a more subtle examination of age trends and windows of ages where predictors have differential effects on outcomes.¹³ With a better understanding of age-dependent associations with ED use, mental health care services could be more anticipatory of critical time-points in children's lives and the use of acute services such as the ED can be avoided.

The objective of this study was to estimate the effects of sex, geographic location, and socio-demographic predictor variables on the frequency of ED visits for mental health care and consequently, the time between ED visits (i.e., an increased frequency would correspond to a shorter time between visits). We wanted to know if and how the relationship between predictor variables and the frequency of ED visits evolves over time. The authors hypothesized that the effects of predictors would vary with the age of children and youth. A new modeling approach for recurrent events was used¹⁴ to estimate effects of predictors that vary by age for children and youth who made mental health visits to EDs in Alberta, Canada, during April 2002 to March 2011. Rather than using age as a predictor in the model, this approach uses the ages of the children and youth as the time unit and permits findings on an individual's longitudinal trajectory. The new modeling approach was needed to handle missing birthdate data at the ED visit (i.e., ages in integer years known rather than time since birth).

Methods

Study design

Using population-based administrative health databases in the province of Alberta, Canada, from April 1, 1999, to March 31, 2011, a retrospective cohort study was performed. The University of Alberta Health Research Ethics Board approved this study.

Study setting and population

Alberta has a uniform, single-payer health system that provides health care to all Alberta residents. The data for the study cohort were extracted from population-based databases by Alberta Health (the provincial ministry of health). The Ambulatory Care Classification System¹⁵ database records ambulatory care visits to all Alberta government-funded facilities (including all 104 EDs) and the

Alberta Health Care Insurance Plan cumulative population registry contains demographic and population data. The analyses focus on the children with at least one ED visit for mental health during the study period.

Study protocol

The Ambulatory Care Classification System database has a main diagnosis field and nine additional fields to capture diagnosis data (Canadian Enhancement of International Classification of Diseases, 10th Revision).¹⁶ All ED visits classified as mental health made by Alberta children < 18 years of age during April 1, 2002, and March 31, 2011, were extracted. An ED visit was classified as mental health if the first diagnosis field had diagnostic codes corresponding to mood disorders mental/behavioral disorders due to psychoactive substance abuse (F10.x–F19.x), schizophrenia/schizotypal/delusional disorders (F20.x–F25.x, F28.x, F29.x), mood disorders (F30.x–F34.x, F38.x, F39.x), neurotic/stress-related disorders (F40.x–F43.x), behavioral syndromes (F50.x, F55.x, F59.x), behavioral/emotional disorders (F90.x–F94.x), disorders of adult personality (F60.x–F69.x), unspecified mental disorder (F99), or toxic effects of non-medicinal substances (T51, T52, T58, T59). In the case of self-harm, if self-injury (X60–X84, T71) was recorded in any of the 10 diagnosis fields, the ED visit was classified as mental health.

Variables extracted included the ED visit date and time, age in years at ED visit, age in years at fiscal year end (March 31), sex (male, female), geographic area of residence (North, Edmonton, Central, Calgary, South) based on the administrative zones for health service delivery, and socio-demographic group. Sex, geographic area of residence, and socio-demographic group were considered predictors.

For the socio-demographic group variable, the first three groups were defined by the level of subsidy provided by the Alberta government to the child's family to offset the costs of provincial health care premiums. While health care in Canada is government funded and all Canadian children have access to health care, Alberta charged an additional annual health care premium to families during most of the study period (2002 to 2009). The three health care premium subsidy groups were as follows: (1) human health services program recipient (a child whose family received income support and other health benefits from the province due to insufficient resources to meet basic needs), (2) government-sponsored program subsidy recipient (a child whose family received partial or full government subsidies for health care insurance premiums or received disability benefits), and (3) regular plan participant (a child whose family received no support from the government for health care premium costs due to sufficient income and resources). The fourth socio-demographic group of children had First Nations status based on treaties between First Nations bands and the Canadian government.¹⁷ Those families did not have to pay health care insurance premiums irrespective of level of income or resources. Families self-identifying as First Nations but not holding formal First Nations status were included in groups 1, 2, or 3.

Key outcome measures

The recurrent events (i.e., the date and time) of ED visits for mental health were the key outcome measures that were analyzed. Note that while time to event is the outcome analyzed, the times to events have a direct relationship with the frequency of events (e.g., shorter times to events will result in higher frequencies of events in a given time period).

Data analysis

Summary statistics (e.g., counts, percentages) describe the demographic characteristics of the extracted cohort and the population. To model the frequency of ED visits for mental health based on predictors, a new marginal model with time-dependent regression coefficients (also referred to

as age-varying coefficients) was considered and applied to the children with at least one mental health presentation to the ED during the study period.¹⁴ Full details of the methodology appear in another paper¹⁴ and a short description for this paper as a [supplementary material](#).

Briefly, the model allowed the estimated effect of predictors to change with the age of the individual. Local linear estimates were obtained with an Epanechnikov kernel function,¹⁸ 2 months as a time unit, a bandwidth of 3 units, and the age window was set to be 1 to 17 years (i.e., 6 to 102 time units). The model included sex, socio-demographic group, and zone as predictors. For each predictor and at each age, an estimate is obtained that forms a continuous, nonlinear function of age. Coefficient estimates, adjusted hazard ratios (aHRs), and pointwise 95% confidence intervals (CIs) are provided for each predictor.

A special feature of the extracted data complicates analyses. Because Alberta Health did not permit the release of birthdates, the times from birth to the ED visit date or age 18 are not known exactly. This missing information coarsens the recurrent visit data and the associated censoring times. That is, there is incomplete information on the censoring times. To overcome the lack of precise censoring time data, the local linear partial score function of the regression parameters is approximated based on the ED visit data with children's birthdates by 100 sets of generated birthdates. For each child, a birthdate was generated from a uniform distribution over an interval based on the child's age in years at the ED visits and at the end of the fiscal year.¹⁴ For example, if a child was 10 years old at an ED visit on November 2, 2005, and 11 at the end of the fiscal year (i.e., March 31, 2006), then the true birthdate would be in the interval November 3, 1995, to

Table 1

Child, ED visit, and population characteristics for Alberta, Canada, 2002–2011

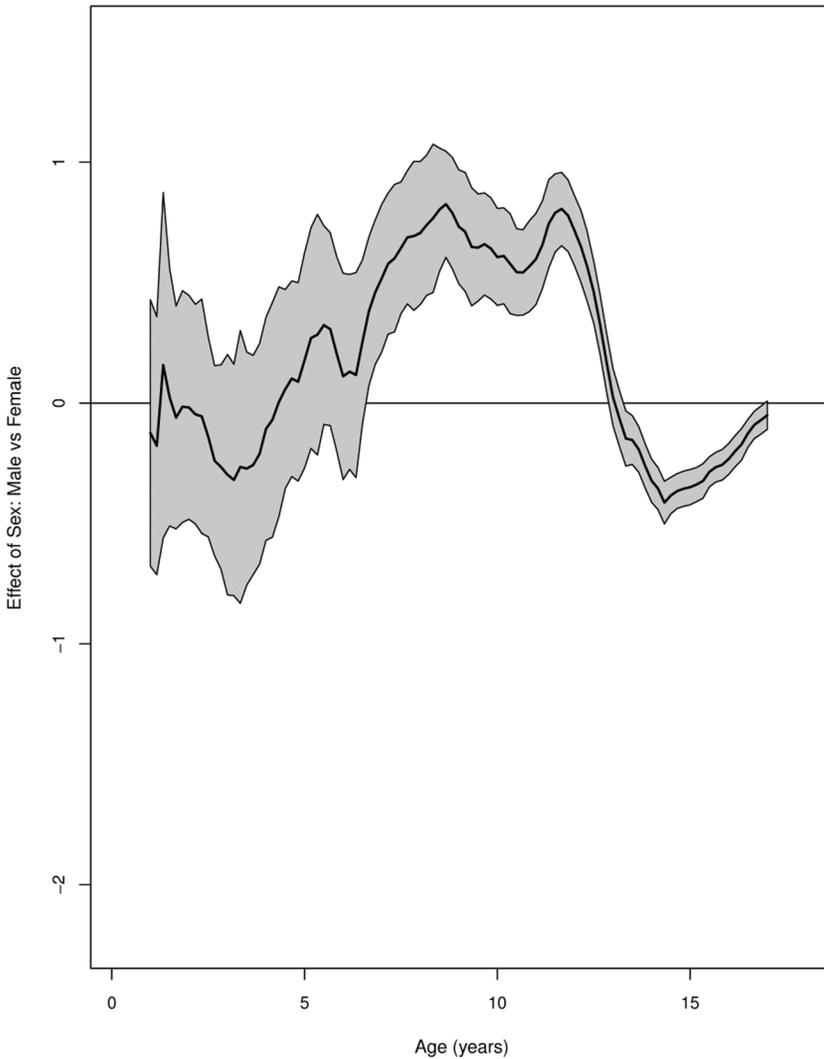
	Mental health cohort		2011 population ^b	
	Patients ^a	ED visits		
Count, <i>n</i>	27,947	41,159	859,812	
Sex, <i>n</i> (%)				
Male	12,095 (43.3)	16,999 (41.3)	441,180	(51.3)
Female	15,852 (56.7)	24,160 (58.7)	418,632	(48.7)
Age group, <i>n</i> (%)				
0–4 years	456 (1.6)	468 (1.1)	257,586	(30.0)
5–9 years	1449 (5.2)	1771 (4.3)	229,000	(26.6)
10–14 years	8449 (30.2)	11,664 (28.4)	227,827	(26.5)
15–17 years	17,593 (63.0)	27,256 (66.2)	145,399	(16.9)
Socio-demographic group, <i>n</i> (%)				
Subsidy based on First Nations status	3785 (13.5)	5856 (14.2)	47,497	(5.5)
Family receipt of government-sponsored subsidy	4098 (14.7)	7003 (17.0)	23,217	(2.7)
Family receipt of human health services subsidy	1804 (6.5)	2909 (7.1)	35,432	(4.1)
No family receipt of subsidy	18,260 (65.3)	2391 (61.7)	753,666	(87.7)
Geographic area, <i>n</i> (%)				
North	5207 (18.6)	7745 (18.8)	115,790	(13.5)
Edmonton	7824 (28.0)	12,000 (29.2)	255,592	(29.7)
Central	4322 (15.5)	6294 (15.3)	106,629	(12.4)
Calgary	8172 (29.2)	11,756 (28.6)	311,395	(36.2)
South	2422 (8.7)	3364 (8.2)	70,406	(8.2)

^aA child's age group, socio-demographic group, and zone are based on the first ED visit

^bAll Alberta children and youth < 18 years of age in 2011

Figure 1

Estimates and 95% confidence intervals (CIs) for the effect of sex from the regression model with age-varying coefficients



March 31, 1995. If a child had multiple ED visits, the intersection of the birthdate intervals generated from each of the visits and the fiscal year ends was used. The resulting estimating equation is solved to obtain the parameter estimates and estimated the associated variance based on the data and the uncertainty arising from an unknown birthdate.

Data were analyzed using R¹⁹ and a specialized R program that called C++ code to perform the marginal regression analysis with time-dependent coefficients.¹⁴

Results

From 2002 to 2011, 41,159 ED visits were made by 27,947 children for mental health reasons (1% of total ED visits made by children). The majority of ED visits were made by children aged 15 to 17 years

(Table 1). Notably, children with ED visits had different demographics (i.e., sex, age, socio-demographic group) from the general population; see Table 1 for the statistics on the population in 2011 for a comparison. Most children had only one ED visit recorded (74.7%, 20,871) and 15.2% (4256) had two visits, 5.4% (1507) had three visits, and 4.7% (1313) had more than three visits.

The analysis under the marginal regression model with time-dependent coefficients revealed the estimated effects of predictors were different for different ages. Figure 1 shows how the estimates varied by age (along with pointwise 95% CIs) for sex. For each age, an estimate is obtained that forms a continuous, nonlinear function of age and selected cross-sectional hazard ratios are provided in Table 2. The 95% CIs are wider for younger ages and narrower for older ages, demonstrating less precision at younger ages because there were fewer ED visits at the younger ages. The coefficient estimates suggested dramatic sex differences for ED use with a change occurring around age 13: (i) males and females had similar ED visit frequencies before starting school (e.g., at 5 years of age aHR = 1.19, 95% CI [0.76, 1.87]), (ii) younger, school-aged males tended to have significantly more ED visits than females (e.g., at 10 years of age aHR = 1.83, 95% CI [1.50, 2.24]), and (iii) adolescent females had significantly higher ED visit frequencies than adolescent males (e.g., at 15 years of age aHR = 0.70, 95% CI [0.65, 0.76]). The cumulative rate functions differed by sex for the younger ages. Graphs depicting risk are presented in a figure (supplementary material, eFigure 1).

In terms of socio-demographic group, higher frequencies of ED visits were observed for children aged > 14 years with First Nations status (Fig. 2a, aHR = 1.18, 95% CI [1.07, 1.30] for age 15 years), and children aged > 8 years from families receiving government-sponsored subsidy (Fig. 2b, aHR = 1.27, 95% CI [1.14, 1.41] for age 15 years) and children between ages 7 to 14 years receiving human health services subsidy (Fig. 2c, aHR = 1.48, 95% CI [1.03, 2.12] for age 10 years) compared to children from families who did not receive a subsidy.

Table 2

Adjusted hazard risk of ED visit and 95% confidence intervals (CIs) for ages 5, 10, and 15 years from the novel marginal regression model with age-varying coefficients for Alberta, Canada, 2002–2011

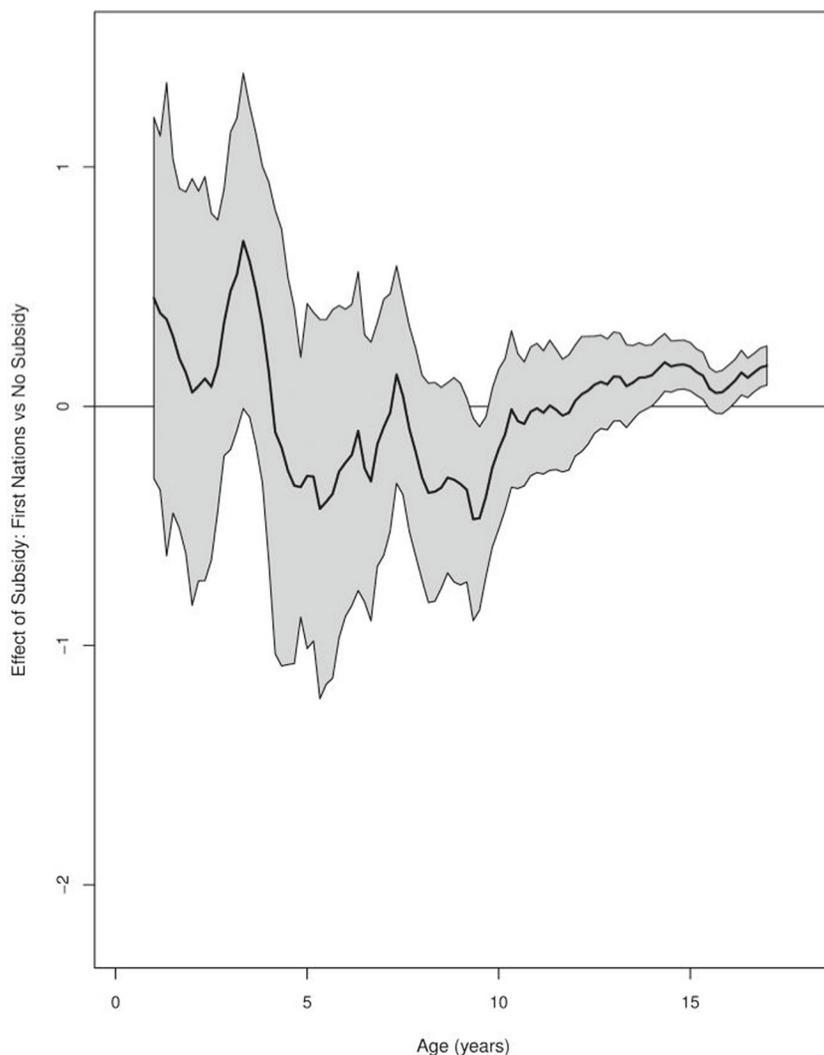
Variable	Estimate [95% CI] ^a					
	Age 5 years		Age 10 years		Age 15 years	
Sex						
Male	1.19	[0.76, 1.87]	1.83	[1.50, 2.24]	0.70	[0.65, 0.76]
Female	Reference					
Socio-demographic group						
Subsidy based on First Nations status	0.75	[0.36, 1.54]	0.83	[0.60, 1.17]	1.18	[1.07, 1.30]
Family receipt of government sponsored subsidy	1.26	[0.73, 2.18]	1.78	[1.41, 2.24]	1.27	[1.14, 1.41]
Family receipt of human health services subsidy	1.14	[0.63, 2.04]	1.48	[1.03, 2.12]	1.18	[1.02, 1.36]
No family receipt of subsidy	Reference					
Geographic area						
North	1.34	[0.71, 2.53]	0.80	[0.59, 1.09]	0.94	[0.84, 1.05]
Edmonton	Reference					
Central	0.94	[0.45, 1.96]	1.11	[0.81, 1.52]	0.93	[0.83, 1.04]
Calgary	0.91	[0.49, 1.70]	1.22	[0.95, 1.57]	0.95	[0.87, 1.05]
South	0.80	[0.49, 1.30]	0.68	[0.46, 1.02]	0.84	[0.73, 0.96]

^aCI confidence interval

Figure 2

Estimates and 95% confidence intervals for the effect of socio-demographic groups from the regression model with age-varying coefficients

a) Subsidy based on First Nations status

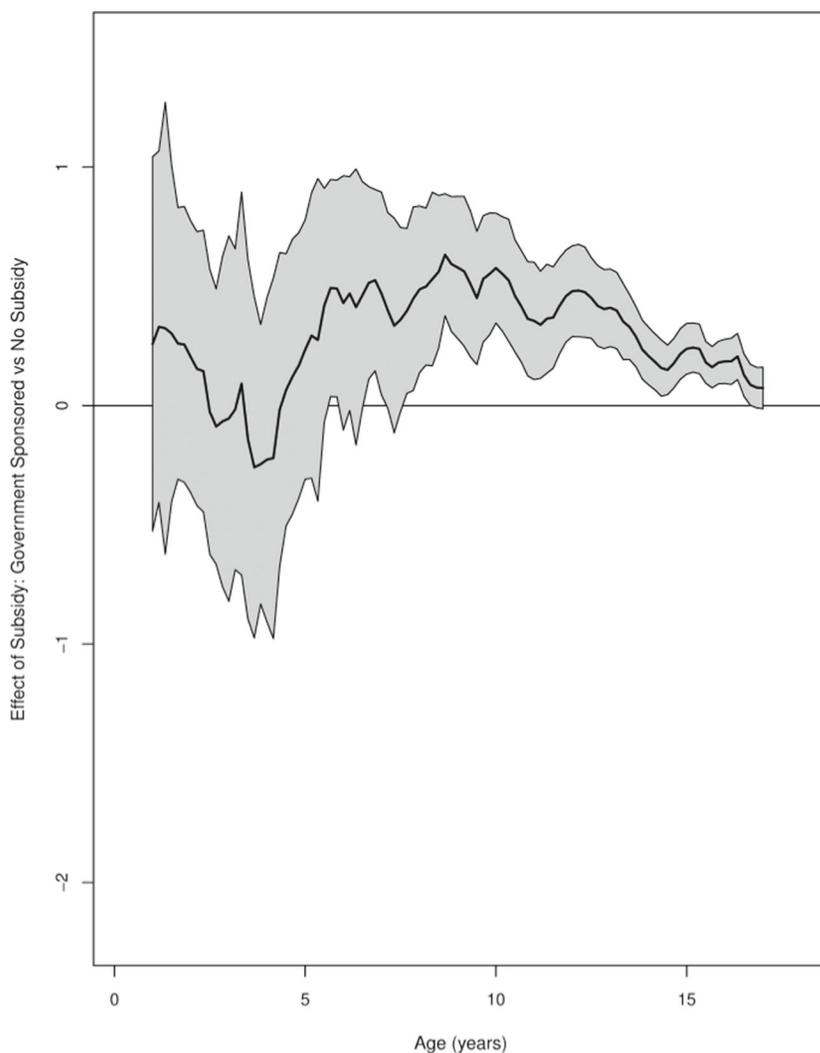


The frequencies of ED visits by children living in different geographic zones of Alberta were similar (supplementary material, eFig. 1), although 15-year olds who lived in southern regions of Alberta had lower frequencies of ED visits than children who lived in Edmonton, Alberta (aHR = 0.84, 95%CI [0.73, 0.96] at age 15).

These results show that the estimates of predictors varied by age. A traditional fixed effects analysis would have had the effect of a predictor be the same for each age. Such a model would not be appropriate for the data. In particular, a model with fixed effects for age would not appropriately represent the relationship among ED visit frequency, sex, and age. The Online Resource provides additional details of the fixed effects analysis (eTable 1).

Fig. 2
(continued)

b) Family receipt of government sponsored subsidy

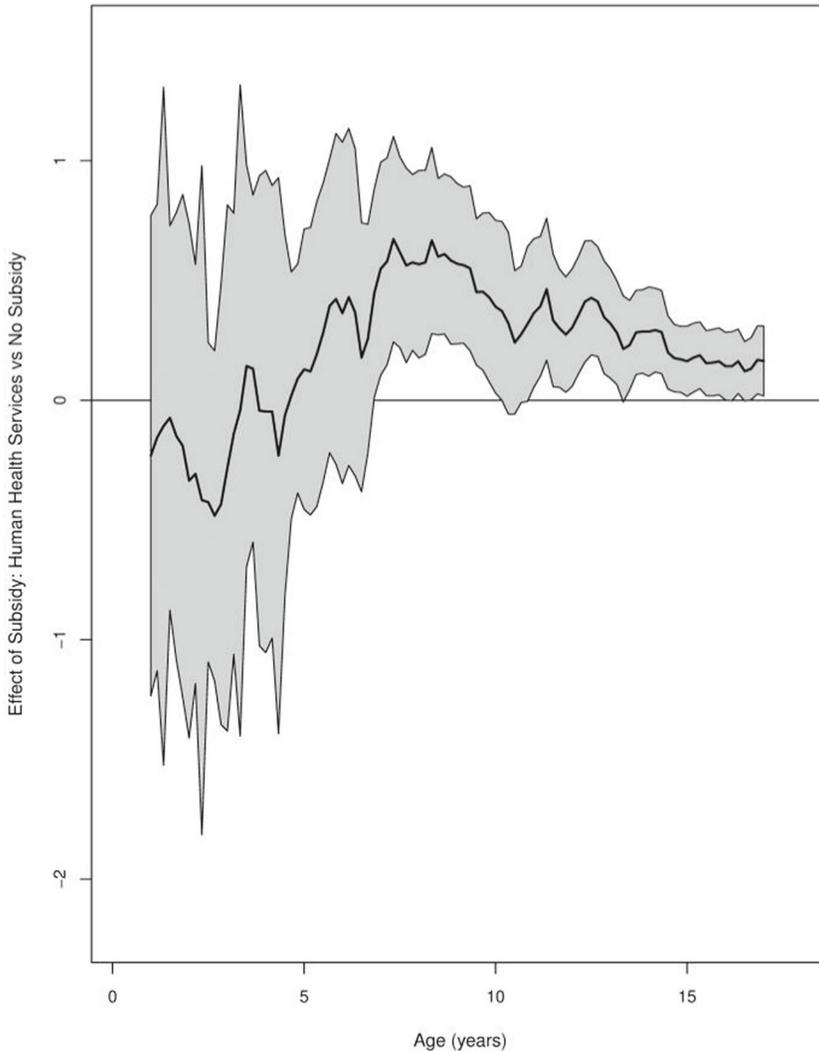


Discussion

Age, race, ethnicity, and sex have been shown to predict ED visits for pediatric mental health care in other studies.⁸⁻¹⁰ The authors wanted to better understand the relationship among age, predictors, and ED visit frequency to allow for a more nuanced examination on how the impact of predictors evolved over age. With a better understanding of age-dependent associations with ED use, mental health care services could be more anticipatory and possibly reduce the use of acute services such as the ED. The authors used large, population-based, administrative data in Alberta during 11 years to estimate the effects of sex, geographic location, and socio-demographic predictors on the frequency of ED visits for mental health care. A novel statistical modeling

Fig. 2
(continued)

c) Family receipt of human health services subsidy



approach provided estimates that were allowed to vary by age. With a child's age used as the time unit rather than modeling age as a predictor and time as the calendar time, the modeling approach provides findings for an individual's longitudinal trajectory. This work showed that the effects of sex, socio-demographic group, and geographic zone on ED visit frequency for mental health care differ with age of the child. Future analyses of children with ED visits for mental health care that ignore age-varying effects will not be representative of how the relationships between predictors and outcome change over age. This study has quantified the relationship between these predictors and ED visit frequency over age.

This new modeling approach provides a key advantage when investigating ED visits among children in that all data were used to determine the age-varying estimates. That is, for estimation of

risk at age 10, all ages of children in the study were used to estimate risk rather than calculating cross-sectional risks. The cross-sectional approach has been used in other ED studies.^{11, 20, 21} This analysis allowed for the examination of age-varying patterns of ED visits across child socio-demographics and geography rather than considering age as a fixed effect.

This approach advances the conventional methodology to better quantify the relationships between predictors and outcomes when these relationships change as a child ages, and allows for these relationships to be quantified at each year of age.

As with any study using administrative data, limitations include that important confounding variables may not have been collected, the true incidence of illness may not be captured, and the reasons seeking ED care are not known. The definition of First Nations status was based on treaties with the Canadian government and did not include other groups such as Inuit and Métis. The analysis methods did not account for children entering (e.g., moving in) or exiting the risk set (e.g., moving out) which may result in some bias in the estimates. Further, the data extraction specifications required children to seek ED care at least once during the study period and for conclusions about all of Alberta's children, additional data would be required for those who did not seek ED care.

The analysis revealed important age-varying effects on the relationship of predictors on mental health ED visit frequency. It demonstrated that a child's age is an essential aspect in any analyses involving pediatric mental health care in the ED. The new marginal model for recurrent events provides an appropriate method to analyze datasets with incomplete information on the censoring data.

Implications for Behavioral Health

The age-dependent association of ED visits with the children's socio-demographics and geography found by this study suggests a need to better understand the role of the ED for mental health care for children and their families over time. The use of mental health care services and resources changes over time²² as do the developmental and social-emotional needs of children. It may be that the ED serves different functions at different points in a child's mental health care trajectory. Understanding these functions could inform mental health care planning so that services are more anticipatory of critical time-points in children's lives and the use of acute services such as the ED can be avoided.

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Compliance with Ethical Standards

The University of Alberta Health Research Ethics Board approved this research and individual participant informed consent was not required.

Conflict of Interest The authors declare that they have no conflict of interest.

Data and Computing Code Data is the property of Alberta Health and the authors are not allowed to provide the data. Requests can be made for the same data from Alberta Health for researchers who meet the criteria for access to confidential data. Researchers are welcome to inquire for further information at Health.RESDATA@gov.ab.ca. R code for the method is available at <http://onlinelibrary.wiley.com/doi/10.1111/biom.12503/supinfo>.

Disclaimer This study is based in part on data provided by Alberta Health. The interpretation and conclusions are contained herein are those of the researchers and do not necessarily represent the views of the Government of Alberta. Neither the government nor Alberta Health expresses any opinion in relation to this study.

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