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Age-varying effects of repeated emergency department presentations for children in Canada

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Abstract

Objectives: Repeated presentations to emergency departments (EDs) may indicate a lack of access to other health care resources. Age is an important predictor of frequent ED use; however, age-varying effects are not generally investigated. This study examines the age-specific effects of predictors on ED presentation frequency for children in Alberta and Ontario, Canada.

Methods: This retrospective study used population-based data during April 2010 to March 2017. Data were extracted from the National Ambulatory Care Reporting System for children aged <18 who were members of the top 10% of ED users in any one of the fiscal years 2011/2012 to 2015/2016 along with a comparison sample from the bottom 90%. A marginal regression model studied the age-varying associations on the frequency of ED presentations with province, sex, access to primary health care provider (for Ontario only), area of residence and lowest neighbourhood income quintile.

Results: There were 2,481,172 patients who made 9,229,156 ED presentations. The effects of sex, lowest income quintile, rural residence, access to primary health care provider and province on the frequency of presentations varied by age. Notably, boys go from having more frequent presentations than girls when aged ≤5 (i.e. adjusted intensity ratio [IR]=1.04 at age 5, 95% confidence interval [CI] = 1.03,1.06) to less frequent for ages 8–11 years and beyond 14 (i.e. IR = 0.80 at age 15, 95% CI = 0.78,0.81). Adolescents aged ≥15 without access to a primary care provider had more frequent presentations compared to those with a primary care provider.

Conclusions: When examining the frequency of ED presentations in children, age-varying effects of predictors should be considered. Our more nuanced examination of age provides insights into how health services might better target programmes for different ages to potentially reduce unnecessary ED use by providing other health care alternatives.

Keywords

emergency department, recurrent presentations, administrative data

Introduction

In many jurisdictions, presentations to emergency departments (EDs) are increasing[1] and ED crowding is a worldwide health issue.[2] Compared to non-frequent ED users, frequent ED users are a relatively small number of patients with a disproportionally larger number of ED presentations.[3] A better understanding of the characteristics of patients with repeated ED use may lead to targeted

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programmes to provide such users with better access to other health care services, and potentially safely reduce ED use. Programmes could be tailored for different ages if the frequent ED use varies by age.

The demand for paediatric ED care has increased over the past decade in a variety of countries, ranging from near 40% in Belgium[4] to 58% in the USA.[5] The reasons for paediatric ED attendance are often complex and involve a variety of factors, such as parental/caregiver socioeconomic characteristics, perception of illness severity, dissatisfaction with primary care services and perception of the advantages of the ED in terms of efficiency and waiting times.[6]

A recent systematic review on the characteristics of paediatric frequent ED users found that they accounted for 9%–42% of all paediatric ED visits.[7] Factors associated with increased paediatric ED use were ethnicity, low parental educational attainment, residency in disadvantaged areas, having at least one chronic health condition and age. Children aged 0–5 years were the most common ED visitors compared to older children.[7] Importantly, studies that have evaluated ED use among paediatric populations have not systematically assessed whether factors associated with the frequency of ED presentations among children remain the same as children grow older. Determining this is very important from a health services planning perspective as children presenting to the ED at different ages may require different approaches in relation to the risk factors that trigger their visits.

Regression modelling approaches are commonly used to draw inferences in studies that have examined the characteristics of children[7] and adults[8] who are frequent ED users. Age is generally considered to be an important factor.[9] The vast majority of studies on different populations have used logistic regression to predict frequent user group membership.[10] Recurrent events models can provide more granular information on the association between predictors and the frequency and timing of ED presentations. Thus, in this study, we use recurrent event models to examine the relationship between age and other predictors on the frequency of ED use among children who frequently use the ED.

We model patients' repeated (i.e. correlated) ED presentations as a function of socio-demographic and geographic predictors in two Canadian provinces. The authors hypothesized that the effects of predictors on frequency of ED use would depend on the age of the child at ED presentation.

Methods

Study design

This retrospective cohort study used population-based health administrative data between 1 April 2010 and 31 March 2017 from the provinces of Alberta and Ontario, Canada. The data used for this study was part of a larger extract where similar methods have been described.[11] This study was approved by the Health Research Ethics Board at the University of Alberta (Pro00078363). The funding organization had no input in the conduct and reporting of the study.

Like all provinces in Canada, Alberta (>4 million residents) and Ontario (>14 million residents) provide medically necessary health care through provincial, universal single-payer health systems. For ED presentations, the Canadian Institute for Health Information records data for 107 EDs for Alberta and 178 EDs for Ontario.[12] In 2016/2017, these EDs had 505,387 and 1,176,811 presentations for children aged 0 to 17 in Alberta and Ontario, respectively.[13] As a collaboration between the Canadian Institutes of Health Research and Canadian Institute for Health Information, the Dynamic Cohort of Complex, High System Users (HSUs)[14] has been created. The Canadian Institute for Health Information used this cohort to extract and link the data for this study.

The Dynamic Cohort identifies HSUs as the top 10% of paediatric patients with respect to the number of ED presentations[14] for each fiscal year (2011/2012 to 2015/2016) for Alberta and Ontario. Control groups were created by selecting random samples of paediatric patients not in the HSU groups using a sampling ratio of four controls to one HSU.[14] For this study, all ED presentations made by patients aged <18 years identified in the HSU and control groups during 1 April 2010, to 31 March 2017, were extracted. Our data extraction included all presentations during the study period for patients who were part of any of the annual HSU or control groups.

Characteristics of the ED presentations, including dates and times, are provided in the National Ambulatory Care Reporting System database. Sex and age in (whole) years at the date of ED presentation are available. Access to primary health care provider data (e.g. family physician, other, none) is also available for the Ontario patients.

Statistics Canada 2011 census data was linked to the patient data to provide area-level data on income and population centre type. Neighbourhood income quintiles are available based on linkages with individual postal code of residence at the time of the ED presentation. Statistics Canada's population centre types are based on technical definitions of census metropolitan area (CMA), census agglomeration (CA) designation, and population size.[15,16] We classified the area of residence into large urban areas (grouped from the categories of core, secondary core and population centres outside CMA/CAs), fringe (all small urban areas within a CMA or CA that are not contiguous with the core of the CMA or CA) and rural.[15]

The recurrent events (i.e. date and time) of ED presentations were the key outcome measures we analysed. The time to events and frequency of events are linked, such that shorter times to events will result in higher frequencies of events in a given time period.

Data analysis

Numerical summaries (i.e. means, medians, standard deviations, interquartile ranges – represented as [25th percentile, 75th percentile]) and counts (percentages) describe patient characteristics. To model the frequency of ED presentations based on predictors, we first used the Andersen-Gill model, which assumes the effects of predictors are the same for all ages.[17] The Andersen-Gill model is similar to the Cox proportional hazards model but allows for multiple events to occur per patient.

We next constructed a marginal model with age-varying (i.e. time-dependent) regression coefficients.[18] This modelling permitted inferences on a child's longitudinal trajectory by using age as the time unit rather than as a predictor. It provided estimates of the age-specific effects of predictors on frequency of ED presentations. Local constant estimates were obtained with an Epanechnikov kernel function,[19] 2 months as a time unit, a bandwidth of one unit, and the age window was set to be 0–18 years (i.e. up to 108 time units). For each predictor and at each age, an estimate is obtained that forms a continuous, nonlinear function of age.

Both models included province, sex, access to primary health care provider (for Ontario only), area of residence, and lowest income quintile indicator as predictors. Adjusted intensity ratios (IRs) and pointwise 95% confidence intervals (CIs) for the frequency of ED presentations are provided for each predictor, with reference categories provided in the figures and tables.

Due to privacy reasons the data extraction did not include birthdates, and the lack of a 'start' for the time to event of ED presentation means that the recurrent event data are coarsened and there is incomplete information on the censoring times. To overcome this issue, the local linear partial score function of the regression parameters is approximated based on the ED presentation data with 100 sets of generated birthdates per patient. For each patient, a birthdate was generated from the uniform distribution over an interval based on the age in the dataset.[18] For example, a hypothetical patient who is 10 years old at an ED presentation on 1 January 2013, has a birthday that is within the interval [2 January 2002 to 1 January 2003] and 100 birthdates would be generated from this interval for this hypothetical patient. 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. A similar approach was also used for the analysis under the Andersen-Gill model.

Data were analysed using R[20] and a specialized R programme that used C++ programming language code to perform the marginal regression analysis with time-dependent coefficients.[18]

Results

There were 2,481,172 patients who made 9,229,156 ED presentations aged <18 years. The median number of ED presentations per patient during the study period was three (maximum was 288). The average age at ED presentation was 7.4a specialized R programme years (standard deviation = 5.8) (see online supplement Table S1). The majority of patients were male (52.9%), from Ontario (69.9%), and lived in large urban areas (74.9%). In Ontario, the vast majority had a family physician (90.1%) and 1.2% had no access to a primary health care provider. The characteristics of patients and ED presentations by province appear in online supplement Table S2.

The first model fit was the multivariable Andersen-Gill model that assumed age invariant effects (online supplement Table S3). Males had less frequent ED presentations compared to females (IR = 0.98, 95% CI 0.97, 0.98). Patients from Alberta had more frequent ED presentations than those from Ontario (IR = 1.22, 95% CI 1.12, 1.23). Patients from neighbourhoods with the lowest income quintile had more frequent ED presentations than those from other income quintile neighbourhoods (IR = 1.16, 95% CI 1.15, 1.16). The results also showed that area of residence affects the frequency of ED presentations. Compared to children living in large urban areas, those living in rural (IR = 1.33, 95% CI 1.33, 1.34) and fringe areas (IR = 1.06, 95% CI 1.05, 1.07) had more frequent ED presentations.

We next fit the marginal model with age-varying regression coefficients. The estimates were continuous, nonlinear functions of age, which demonstrated clear patterns. Figure 1 shows the IRs for the associations between the frequency of ED presentations and sex varied by age (along with pointwise 95% CIs). Compared to girls, boys had more frequent ED presentations (IR >1) at ages younger than 6 and less frequent ED presentations (IR<1) at ages 8 to 11 and older than 14. The teenage years show a dramatic switch from greater frequency of ED presentations for boys to greater frequency among girls. To more easily see the estimates, the IRs for ages 5, 10, and 15, are provided in online supplement Table S3. The IR is 1.04 (95% CI 1.03, 1.06) at age 5 years and becomes 0.80 (95% CI 0.78, 0.81) at age 15 years.

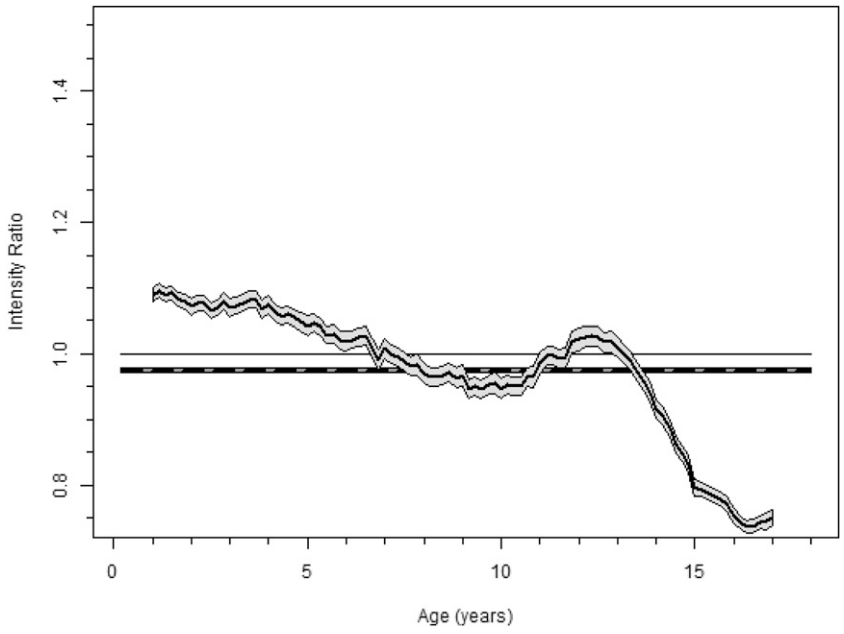

Figure 1. Male versus female intensity ratio estimates and 95% confidence intervals, age-invariant coefficients (horizontal line and bar) and age-varying coefficients (thick line). (Reference line of intensity ratio = 1 also depicted.)

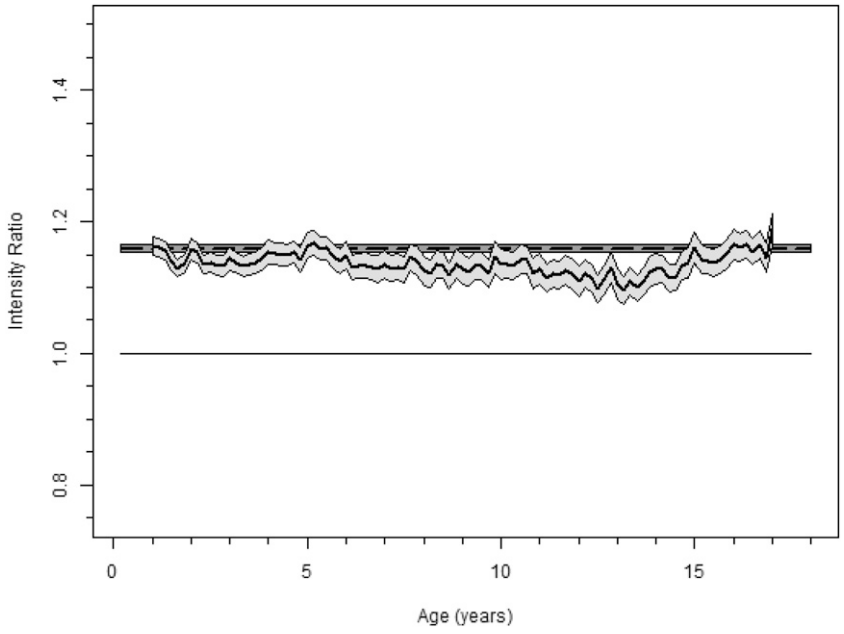

Figure 2. Lowest neighbourhood income quintile versus all other quintiles/missing/not applicable intensity ratios and 95% confidence intervals, age-invariant coefficients (horizontal line and bar) and age-varying coefficients (thick line). (Reference line of intensity ratio = 1 also depicted.)

For all age groups, patients from neighbourhoods with the lowest income quintile had more frequent ED presentations (Figure 2). The IRs were larger than 1.1 for all ages but showed some trends over age: they decreased for ages 5 to 12, increased for ages 13 years and higher.

For patients in Ontario, the estimates of the absence of a primary care provider varied over ages (Figure 3). The IRs

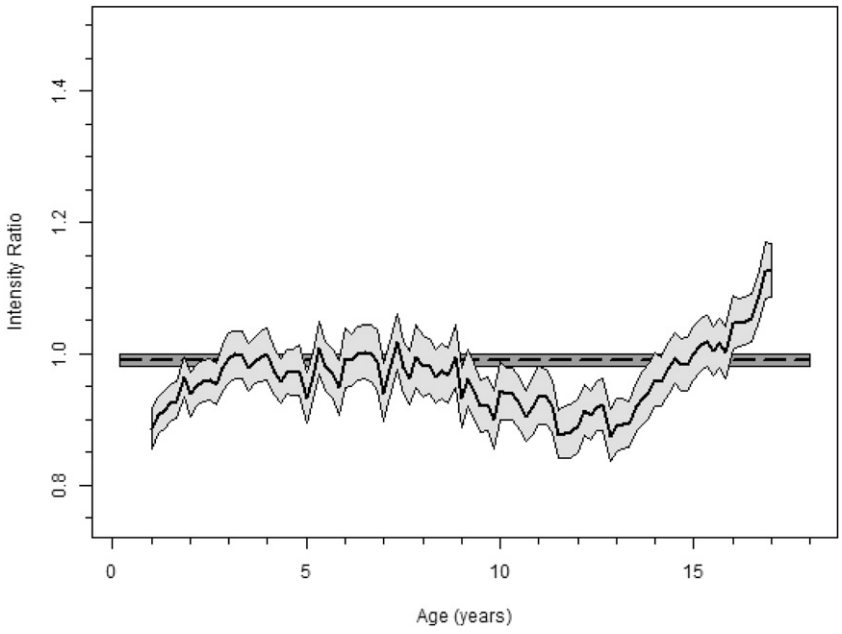

Figure 3. No access to primary care provider versus family physician/others/missing/unknown/unavailable intensity ratio estimates and 95% confidence intervals, age-invariant coefficients (horizontal line and bar) and age-varying coefficients (thick line). Ontario only.

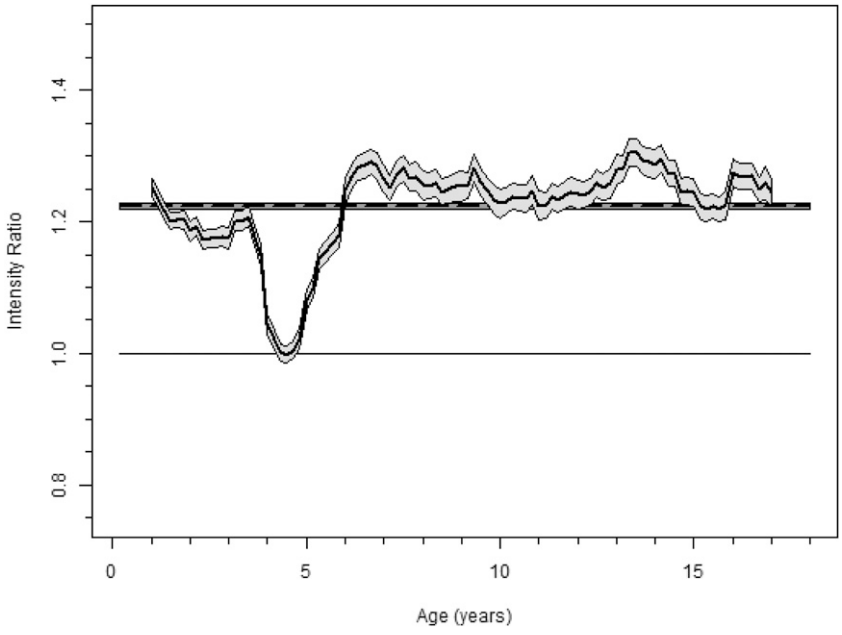

Figure 4. Alberta versus Ontario intensity ratio estimates and 95% confidence intervals, age-invariant coefficients (horizontal line and bar) and age-varying coefficients (thick line). (Reference line of intensity ratio = 1 also depicted.)

indicated that children at the youngest ages (<3 years) had less frequent ED presentations, then from 3 to 9 years old about the same frequency until the frequency decreases during about 9–14 years old before the frequency increases again.

For almost all ages, patients from Alberta had more frequent ED presentations than patients from Ontario (Figure 4). There were some change points in the IRs. The IR decreased from 1.2 to nearly 1 for the ages of 1–4 years. The IR increased to nearly 1.3 for ages 5 to 7 and then remained relatively steady before increasing again for ages 11 to 13 and declining again between the ages of 13–16.

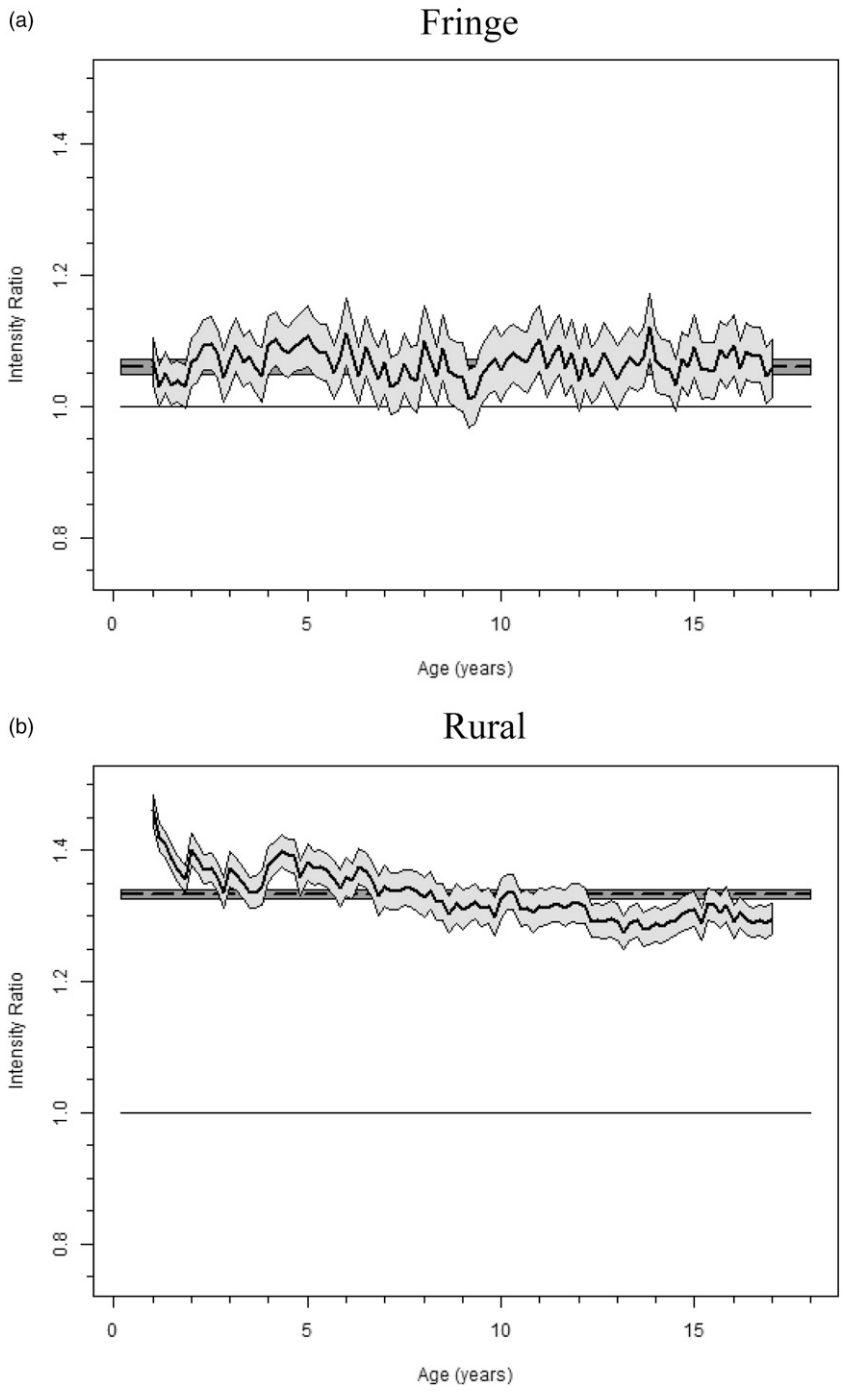

Figure 5. Fringe and rural versus large urban area/missing/not applicable/unavailable intensity ratio estimates and 95% confidence intervals, age-invariant coefficients (horizontal line and bar) and age-varying coefficients (thick line). (Reference line of intensity ratio = 1 also depicted.)

The results for the different areas of residence are shown in Figure 5. Compared to large urban areas, patients from the fringe area generally had more frequent ED presentations; however, the IRs did not vary much over age. Patients from rural areas had larger IRs and these IRs were largest for the youngest ages (<5 years) and then declined from 5 to 13 years of age. The cumulative intensities are plotted for the large urban area and other predictors in online supplement Figure S1.

Discussion

We explored 9,229,156 ED presentations made by 2,481,172 patients from a paediatric cohort of HSUs of EDs

and controls in two provinces in Canada to examine the effect of age and predictors on repeated ED presentations. The results showed that the effects of sex, neighbourhood income, rural area of residence, primary care provider access and province on the frequency of ED presentations varied over age. Boys go from having more frequent presentations than girls when aged ≤5 to less frequent for ages 8–11 years and beyond 14. Patients from neighbourhoods with the lowest income quintile had more frequent ED presentations, with decreased IRs for ages 5 to 12 and increased IRs for ages ≥13. Compared to children living in large urban areas, those living in rural areas had more frequent ED presentations, particularly patients of the youngest ages. Adolescents aged ≥15 without access to a primary care provider had more frequent presentations compared to those with a primary care provider. Patients from Alberta had more frequent ED presentations than those from Ontario, with the highest frequency occurring for ages under 4 and greater than 6 years of age.

The effects of living in fringe areas did not vary much by age. Compared to patients in large urban areas, patients from fringe areas generally had more frequent ED presentations.

Our results suggest that the association with sex on the frequency of ED presentations changes with age. This may help to explain the contradictory findings in the literature. Multiple studies have examined predictors of ED frequency and these studies generally focus on predicting frequent user group membership (e.g. low or high ED use)[7,11] or the number of ED presentations during a specific time period.[21] Younger children have been reported to have greater ED use than older children.[7] Mixed results have been reported on the association of sex, with some studies indicating females are more likely[22] and others indicating that males are more likely[23] to be frequent ED users.

Other studies have also had mixed results on the association between area of residence and ED use.[22,24] Residence in a lower income neighbourhood has been shown to be associated with frequent ED use,[25] and we have shown that this association varies by age. Prior studies have also shown that access to a primary care provider is associated with lower ED use.[25] Our results suggested that the association between primary care access and ED use varied across different ages. Few authors use recurrent event methods to estimate the rate of repeated ED presentations for adults[26] and, to our knowledge, only one study on repeated mental health presentations to EDs among children has also considered age-varying effects.[27] That Alberta-focused study, like our own, also showed dramatic sex differences that varied with age and demonstrated age-varying effects of income.

The age-varying effects on the relationship of predictors on ED presentation frequency have several health services implications. Emerging evidence suggests that limited access to appropriate primary care[28] and the characteristics of care networks (e.g. degree of coordination between primary care and specialists)[29] impact ED use. As such, our findings suggest that improved primary care for areas outside the most urban centres may improve the appropriateness of health care for all ages, and larger improvements for younger ages could be made in the rural and suburban areas. Telehealth options to offer ED services for children with low-complexity complains may offer an alternative to reduce frequent ED use, particularly in the absence of primary care services.[30]

The changing age-specific IR for the lowest neighbourhood income quintile suggests that the greatest effect of income on need for ED care is in the early teen years and special supports for such patients may be beneficial. The dramatic changes in the effect of sex over age suggest that tailoring health delivery programmes by sex and age group may be warranted, with particular attention to boys aged less than five and girls aged at least 14 years. Interventions aimed at meeting the health care needs of teenage patients, particularly teenaged girls, may be useful in improving access to care and reducing ED utilization by these demographic groups.

The provincial differences may suggest that approaches in Ontario could be considered in Alberta to potentially reduce ED use.

Limitations

There are four main limitations to this study. First, there are the potential errors in the data obtained from paper-based sources.

Second, the results may not be generalizable to populations in other jurisdictions.

Third, there may be other important predictors that were not available in the database and not included in the modelling. In particular, data could not be linked with other data sources to determine death dates, and patients are assumed to be alive to age 18 or the study end. However, the death rate in the paediatric population is low and the likely small number of deaths would not have changed the overall results.

Fourth, we did not focus on specific diagnoses or chronic conditions. Identifying patients with chronic conditions is not straightforward from diagnostic codes or other ED data and, even if such patients could be identified, our dataset would not include when such a condition was first diagnosed.

Conclusion

Many factors contribute to repeated ED use, and this research provides a better understanding of how the impact of predictors on ED frequency changes with age among paediatric populations. This more nuanced examination of age provides insights into how health services might better target programmes for children of different ages to potentially reduce unnecessary ED use by providing other health

care alternatives. Specifically, interventions addressing the health needs of frequent users at early teen ages, and sex-specific interventions within these age groups (i.e. teenage girls), may be beneficial in reducing the need for ED presentations in these age groups.

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Declaration of conflicting interests

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

Ethics approval

This study was approved by the Health Research Ethics Board at the University of Alberta (Pro00078363).

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Supplemental material

Supplemental material for this article is available online.

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