Space and time clustering of adolescents' emergency department use and post-visit physician care for mood disorders in Alberta, Canada: A population-based 9-year retrospective study

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ABSTRACT

OBJECTIVES: We used a statistical cluster detection technique to identify geographic areas with higher numbers of adolescents who 1) presented to an emergency department (ED) for a mood disorder, and 2) were without a physician follow-up visit for mental health within 30 days of an ED visit.

METHODS: We conducted a population-based analysis of ED visits ($n = 6,829$) made by adolescents aged 10–17 years ($n = 5,877$) using administrative databases from Alberta, Canada (2002–2011). Statistical analyses included summaries, directly standardized rates (DSRs per 100,000), and the spatial scan cluster test.

RESULTS: Sex- and age-adjusted DSRs increased by 21.8% from 2002 to 2011 (160.2/100,000 to 195.1/100,000). Northern Alberta had consistently higher DSRs than other areas of the province and areas in the north, southwest and central parts were identified as geographical and temporal clusters with relative risks of 1.67, 2.78 and 1.42 respectively. Many of these areas also had higher relative risks for adolescents who did not have a mental health-related visit with a physician within 30 days of the ED visit. About 32% ($n = 1,870$) did not have a post-ED physician visit.

CONCLUSION: The potential clusters identified may represent geographic areas with higher disease severity or more acute care sought because of less availability of other services. The clusters are not all likely to have occurred by chance and further investigations and discussions with local health care policy-makers about reducing the number of ED visits for mood disorders and increasing physician follow-up after the ED visit is an important next step.

KEY WORDS: Adolescence; cluster analysis; space-time clustering; disease clustering; emergency services; mood disorders

In their lifetimes, 7.8% of Canadian adolescents aged 15 to 18 will meet criteria for depression with differing prevalence between boys and girls (4.3% versus 11.1%).[1] Global burden of depressive disorders is significant. In 2010, these disorders accounted for the most disability-adjusted life years (DALYs) caused by mental and substance use disorders with the highest proportion of total DALYs occurring in young people aged 10 to 29 years.[2] As compared to depression onset in adulthood, depression in adolescence is associated with more impaired social and occupational function, poorer quality of life, and greater medical and psychiatric co-morbidities.[3–5] Greater symptom severity, more lifetime depressive episodes, and more suicide attempts[3,6] have also been associated with earlier disorder onset, making treatment during adolescence vital.

Most depressed Canadian adolescents do not receive mental health services. In an examination of 12-month service use rates, Cheung and Dewa reported that 40% of 15 to 18 year olds suffering from major depression had not used any health services for mental health reasons.[7] More recent Alberta-based research has suggested that mood-based crises are among the most frequent reasons for pediatric mental health emergency department (ED) visits.[8] A related study reported adolescents aged 13 to 17 were 1.5 times more likely to return for subsequent ED care compared to 6 to 12 year olds,[9] and that within 72 hours of ED discharge, 6% of children and adolescents diagnosed with a mood disorder will return for further acute care.[9] Combined, this body of Canadian literature suggests that Canadian adolescents are engaging a pattern of acute mental health services use with little to no receipt of community-based or primary care health care.

Large, national efforts to improve access to and receipt of mental health services in childhood and adolescence are ongoing (e.g., Mental Health Commission of Canada[10]). Complementary to these efforts is the use of statistical

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surveillance techniques in Canada's health databases as a practical and cost-effective strategy to reveal patterns of mental health resource use and inform health resource planning. We conducted a population-based study to examine emergency mental health care and follow-up care by adolescents in Alberta, Canada using a statistical surveillance technique. In this study, we identified geographic areas with higher numbers of adolescents 1) presenting to the ED than expected by chance alone, and 2) who presented to the ED but did not have a mental health-related physician follow-up visit within 30 days after an ED visit.

METHODS

Data sources and variable description

Alberta Health provided the population-based data from two databases: 1) the Ambulatory Care Classification System (ACCS[11]) database, which records ambulatory care visits to all Alberta government-funded facilities (including 104 EDs), and 2) the Alberta Health Care Insurance Plan cumulative population registry, which contains demographic and population data.

The ACCS database has a main diagnosis field and nine additional fields to capture diagnosis data (Canadian Enhancement of International Classification of Diseases, 10th Revision; ICD-10-CA[12]). All ED visits made by Alberta adolescents aged 10 to 17 years during April 1, 2002 and March 31, 2011, where the first diagnosis field had diagnostic codes for a mood disorder (F30.x-F34.x, F38.x-F39.x[13]), were extracted.

Geographic data were geo-coded to 70 subregional health authorities (sRHAs) which constitute five provincial health Zones (North, Edmonton, Central, Calgary, South) by Alberta Health along with latitudes and longitudes for population-based geographic centres (centroids). Population data included counts by sex and age (in years) and sRHA of residence at fiscal year end. Two age groups were formed (10–14, 15–17).

Adolescents with ED visits were linked with the Physician Claims File to obtain all physician claims (hereafter physician follow-up visits) within 30 days of the ED visit. This linkage provided the date of the physician claim and up to three diagnosis fields (International Classification of Diseases, 9th Revision – Clinical Modification; ICD-9-CM[14]). We identified mental health physician follow-up visits (those claims with either the first diagnosis field code as 291.x, 292.x, 303.x, 304.x, 305.x, 295.x, 297.x, 298.x, 296.x, 300.4, 311, 300.x, 308.x, 306.x, 307.x, 301.x, 302.x, 300.16, 309.x, 312.x, 313.x, 314.x, 300.9, 980.x, 981, 986, 982.x, 987.x, E95.x, 994.7, or any additional diagnostic fields matching the intentional self-harm category code E95.x, 994.7). We identified adolescents who had at least one ED visit for a mood disorder but did not have any mental health-related physician follow-up visits within 30 days of the ED visit. The University of Alberta Ethics Board provided ethics approval for the study.

Data analysis

Numerical summaries (e.g., counts, percentages) describe the demographic characteristics of adolescents with an ED visit for a mood disorder and the Alberta adolescent population. Crude and sex and age-group directly standardized rates (DSRs) were calculated (with corresponding 95% confidence intervals [CIs]). The Mann-Kendall trend test was used to assess trends in the crude rates. The adolescent population aged 10 to 17 years in Alberta as of March 31, 2003 was used as the reference population for DSRs. ED visits were excluded from analyses if sRHA of residence was missing.

The Kulldorff-Nagarwalla (KN) spatial scan test[15] is a popular statistical cluster detection technique. Circles of varying radii are created around an area (i.e., sRHAs in our data) to form zones. A likelihood ratio test compares the risk of being a case inside and outside each zone, and the maximum likelihood ratio across all zones is identified as the most likely cluster. A Monte Carlo method is used to determine the p-value. To identify spatio-temporal clusters, the zones are cylinders (i.e., the height characterizes the time). We used the KN test to identify geographic areas over time with excess numbers (clusters) of adolescents with mood disorder ED visits and adolescents without 30-day physician follow-up (spatio-temporal clustering). We used a space window of up to 50% of Alberta's population and a time window of 1 year. All tests used the sRHAs as the geographic boundaries and were adjusted by age group and sex. Further, we used the KN test to identify sRHAs that were purely spatial clusters for each of the last two fiscal years. These two years are the most recent years of data and may be more indicative of current data than earlier years. We reported the significant clusters identified as well as DSRs (with 95% CIs[16]). A p-value less than 0.05 was considered to be statistically significant. Data were analyzed using S-Plus software[17] and SaTScan[18] was used for the cluster detection analyses. The Manifold System[19] was used to produce maps of results.

RESULTS

Study cohort description

A total of 6,839 ED visits for mood disorders were made by 5,877 adolescents during the study period. Ten ED visits (0.15%) were excluded from the analysis because of missing geographic data, resulting in 6,829 ED visits available for analysis. The majority of adolescents who had mood disorder ED visits were females (64.6%), 15–17 years of age (72.0%), and were distributed across the province (Table 1). Females and adolescents aged 15–17 years had disproportionately more ED visits than would be suggested by the population distribution (Figure 1a). Increasing trends over time were seen for males aged 10–14 ($p = 0.048$) and aged 15–17 ($p = 0.016$), and for females aged 10–14 ($p = 0.029$). When adjusted by sex and age group, the DSRs per 100,000 for adolescents with mood disorder ED visits remained relatively steady during the first 5 years and showed increases from 2008 to 2011. Across the five geographic Zones in Alberta, there was variability among years and the North, Central, and South Zones (the latter to a lesser extent) of Alberta had disproportionately more adolescents with ED visits than would be suggested by the population distribution (Supplementary Table 1).

Approximately 32% of adolescents with an ED visit for a mood disorder did not have a mental health follow-up with a physician

Table 1. Socio-demographic and geographic characteristics of 1) adolescents with an ED visit for a mood disorder and 2) adolescents without a 30-day physician follow-up visit after the ED visit as compared to total ED visits by adolescents for mood disorders, and the Alberta adolescent population aged 10–17 years (as of March 31, 2011)

	Adolescents with an ED visit		Adolescents without a 30-day physician follow-up visit		ED visits		Alberta population n (%)
	Total n (%)	Per fiscal year Median (range)	Total n (%)	Per fiscal year Median (range)	Total n (%)	Per fiscal year Median (Range)	
All	5877	640 (591–741)	1870	205 (167–259)	6829	744 (680–861)	373,201
Sex							
Female	3798 (64.6)	409 (388–487)	1206 (64.5)	130 (111–165)	4450 (65.2)	480 (446–572)	181,352 (48.6)
Male	2079 (35.4)	230 (199–272)	664 (35.5)	72 (56–98)	2379 (34.8)	266 (228–309)	191,849 (51.4)
Age group (years)							
10–14	1647 (28.0)	179 (167–221)	530 (28.3)	58 (49–71)	1866 (27.3)	198 (182–257)	227,812 (61.0)
15–17	4230 (72.0)	463 (422–535)	1340 (71.7)	149 (116–188)	4963 (72.7)	546 (498–629)	145,389 (39.0)
Provincial zone							
North	1138 (19.4)	137 (92–148)	472 (25.2)	51 (33–83)	1344 (19.7)	150 (100–177)	50,144 (13.4)
Edmonton	1368 (23.3)	151 (138–168)	422 (22.6)	45 (41–57)	1576 (23.1)	175 (154–189)	111,479 (29.9)
Central	961 (16.4)	106 (72–133)	312 (16.7)	34 (21–57)	1159 (17.0)	129 (90–160)	47,834 (12.8)
Calgary	1893 (32.2)	200 (174–293)	537 (28.7)	61 (51–66)	2171 (31.8)	233 (198–342)	132,963 (35.6)
South	517 (8.8)	55 (54–63)	127 (6.8)	14 (7–26)	579 (8.5)	63 (60–72)	30,781 (8.2)

within 30 days. During the study period, females and adolescents aged 15–17 years had fewer follow-up visits (Figure 1b) and there was no evidence of a statistically significant trend over time for each sex and age group. When adjusted by sex and age group, the DSRs for adolescents without a 30-day physician follow-up visit after an ED visit increased over the study period from 49.9 in 2002/2003 to 57.7 in 2010/2011 (Supplementary Table 2). Across the five geographic Zones in Alberta, the North Zone of Alberta had disproportionately more adolescents without physician follow-up than would be suggested by the population distribution.

Geographical and temporal clustering
Adolescents With ED Visits for Mood Disorders
Across the study period, three potential spatio-temporal clusters of adolescents with ED visits for mood disorders (cases) were identified. The annual number of adolescents with ED visits per 100,000 was 175.9 for the province. The first potential cluster contained the vast majority of the North Zone during April 1, 2007 to March 31, 2011 (282.7 annual cases per 100,000, $p < 0.001$). A single sRHA in the southwest part of the Central Zone was identified as a second potential cluster during April 1, 2005 to March 31, 2009 (486.7 annual cases per 100,000, $p < 0.001$). A third potential cluster was identified in the Central Zone during April 1, 2008 to March 31, 2011 (245.9 annual cases per 100,000, $p < 0.001$). These three clusters had relative risks of 1.67, 2.78 and 1.42 respectively (Table 2a, Figure 2a). The relative risk estimate quantifies the risk of being a case inside the cluster compared to the risk outside the cluster.

The KN test was also applied to identify purely geographical clusters for each year and we focus our results on the last two fiscal years. In 2009/2010, three potential clusters were identified. These were concentrated in parts of the North Zone (DSR 305.46 per 100,000, $p < 0.001$), the eastern part of the Central Zone (DSR 290.24 per 100,000, $p = 0.011$) and the western part of the Central Zone when combined with a sRHA from the North Zone (DSR 364.35 per 100,000, $p = 0.036$). The DSR for sRHAs not involved in clusters was 160.83 (95% CI 146.89–175.76). The relative risks for

the three clusters were 1.72, 1.61 and 1.98 respectively. One sRHA (Aspen East) from the first cluster in 2009/2010 was a potential cluster in 2010/2011 and sRHAs within the Calgary Zone formed the other potential cluster. The DSR for the sRHAs that were not part of clusters was 177.78 per 100,000 (95% CI 163.72–192.74) whereas the first cluster had a DSR of 498.15 per 100,000 ($p < 0.001$) and the second cluster had a DSR of 280.87 per 100,000 ($p = 0.011$). The relative risks in the first and second clusters were 2.61 and 1.52 respectively.

Adolescents With ED Visits for Mood Disorders Without 30-day Physician Follow-up
Three clusters of adolescents with an ED visit for a mood disorder and without 30-day physician follow-up (cases) were identified (Table 2b, Figure 2b). The first two potential clusters have the same sRHAs as identified previously and slightly different time periods. The third potential cluster contains several sRHAs in the Central Zone, some of which were identified as part of the third cluster when examining adolescents with an ED visit for a mood disorder.

When examining purely geographic clusters for the 2009/2010 and 2010/2011 years, the KN test identifies only one cluster for each year. In 2009/2010, the cluster contains most of the sRHAs in the North Zone (DSR 129.16 per 100,000, $p < 0.001$). This geographic area was slightly larger than the potential cluster of ED cases identified. In 2010/2011, the potential cluster (DSR 122.81 per 100,000, $p < 0.001$) is a subset of the cluster identified for 2009/2010. Some of these sRHAs were also part of a potential cluster of ED cases. All the sRHAs not involved in the potential cluster had DSRs of about 51 per 100,000 for each of the years.

DISCUSSION
Our population-based study spanned nine fiscal years and showed trends over time and geography for adolescents who presented to the ED for mood disorders in Alberta. The rates of adolescents presenting to an ED for a mood disorder increased during the
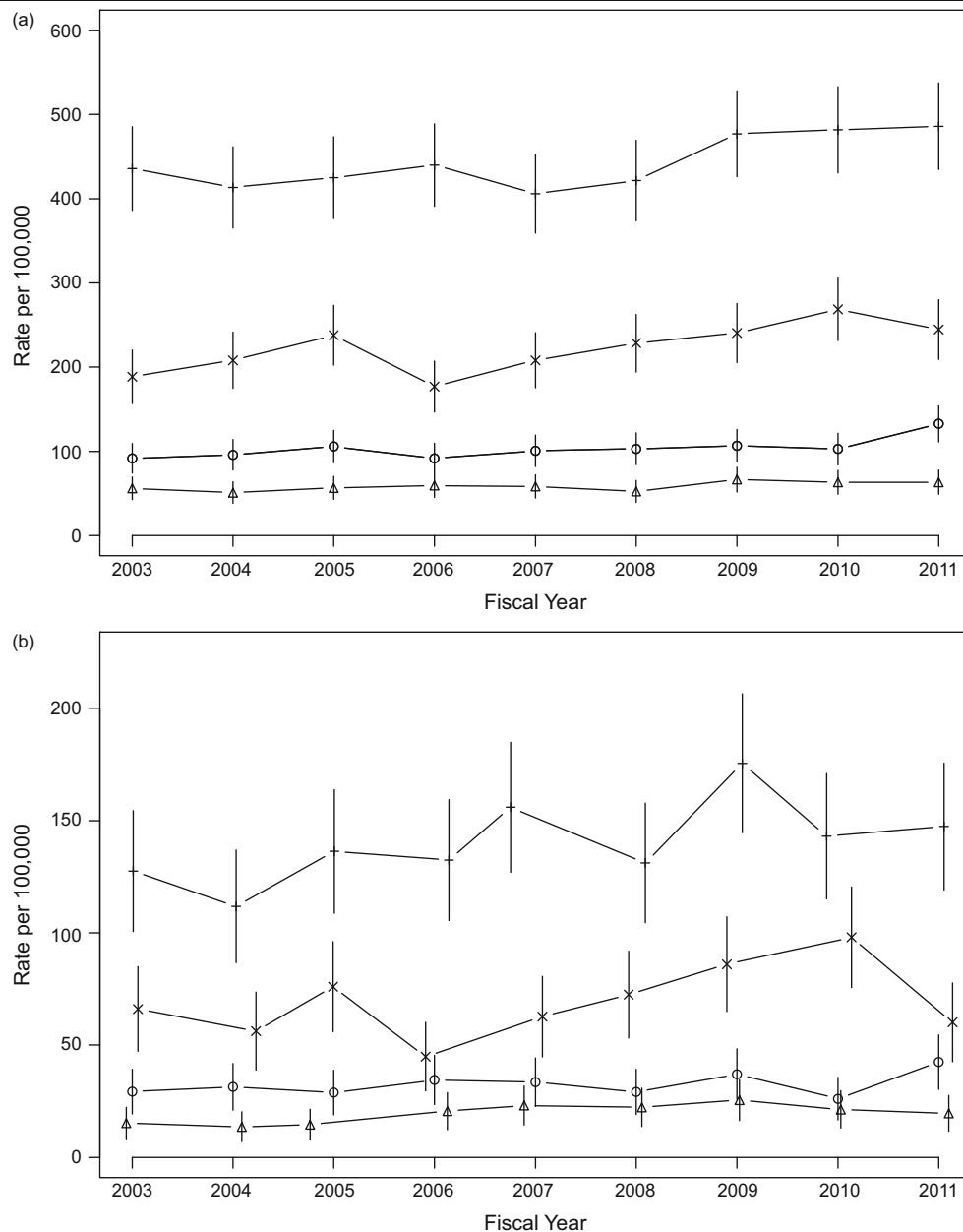
Figure 1. Crude rates per 100,000 adolescents aged 10 to 17 years with 95% confidence intervals (CIs) by sex and age group for each fiscal year for: a) adolescents with ED visits for a mood disorder, and b) adolescents with an ED visit for a mood disorder but without a 30-day physician follow-up

Legend: Females aged 15–17 (+), males aged 15–17 (×), females aged 10–14 (○), and males aged 10–14 (△)

study period, with females aged 15 to 17 having the highest rates. Sex- and age-adjusted directly standardized rates were relatively stable over time but showed variation among the health Zones in Alberta.

We identified three potential geographic and temporal clusters and identified some potential purely geographic clusters during the 2009/2010 and 2010/2011 fiscal years. These potential clusters were mainly in the north and central regions of the study region and the different analyses produced some different results. The potential clusters identified may represent real cluster areas that have a higher severity of mood disorders in adolescents requiring emergency care or may represent areas with less

availability of other health services. These findings are consistent with previous population health summaries of Alberta data that have shown that the least socio-economically advantaged Alberta youth are more likely to live in rural areas of the province (e.g., North, Central, or South).[20] These less advantaged youth were more likely to be male, visit EDs more frequently (most frequent reasons for visit are psychiatric or behavioural in nature), and visit primary care physicians 5 or more times per year compared to more advantaged youth living in larger urban centres (e.g., Calgary or Edmonton). In terms of ED visits, Alberta summary data have indicated that females over 16 years were more likely than males to have multiple visits, but this trend

Table 2. Clusters of a) adolescents with ED visits for mood disorders and b) adolescents without a 30-day physician follow-up after an ED visit for a mood disorder (cases) identified over space and time

Cluster	Time frame	Location (sRHAs)	Population	Cases	Expected cases	Observed/ expected	Relative risk	*p*-value
a) Adolescents with ED visits for mood disorders								
1	April 2007 to March 2011	Aspen Central Aspen North Aspen East Peace NW Peace NE Peace SE Peace SW High Level La Crete Northern Lights Northwest Fort McMurray	45,696	513	319.19	1.61	1.67	<0.001
2	April 2005 to March 2009	Clearwater	2522	49	17.71	2.77	2.78	<0.001
3	April 2008 to March 2011	Didsbury-Strathmore Wetaskiwin-Hobbema Ponoka Lacombe Red Deer Olds Drumheller-Hanna Region 5 Southwest	44,854	337	241.07	1.40	1.42	<0.001
b) Adolescents without a 30-day physician follow-up after an ED visit for mood disorders								
1	April 2006 to March 2010	Aspen Central Aspen North Aspen East Peace NW Peace NE Peace SE Peace SW High Level La Crete Northern Lights Northwest Fort McMurray	45,696	239	101.92	2.35	2.54	<0.001
2	April 2007 to March 2010	Clearwater	2522	22	4.28	5.15	5.19	<0.001
3	April 2008 to March 2010	Lacombe Red Deer Drumheller-Hanna Stettler-Consort Region 5 Northwest Region 5 Southeast Region 5 South Central Region 5 Southwest	32,258	70	36.17	1.94	1.97	0.002

starts to decrease after the age of 19 years.[20] In terms of primary care physician visits, Alberta summary data have shown that the number of visits to a primary physician for females and males on income supports (i.e., welfare) starts to increase at ages 10 and 15 years respectively.[21] For females on welfare, the number of primary care physician visits decreases between the ages of 20–65 years, while for males the numbers remain consistent between 20–65 years. Similarly, Alberta summary data shows that mental health and other health resources are less available in rural areas of the province. This lack of availability has contributed to the higher rates of ED visits in North, Central, and South Zones of the province and their lower rates of primary care visits per weighted population.[22]

The KN spatial scan is a popular cluster detection method and cluster detection methods have been used to identify "hot spots" of a variety of diseases. A few studies have focused on mental health conditions such as depression[23] and self-inflicted injury.[24–28] To our knowledge, we are the first to examine geographic clustering of adolescents aged 10 to 17 years who presented to EDs for mood disorders.

While the KN spatial scan can identify potential clusters, a limitation of all cluster detection methods is that they cannot determine if an identified cluster is a real cluster. Further, the KN spatial scan is most appropriate for identifying circular clusters that are close in proximity and for finding the most likely cluster. Secondary clusters and clusters with irregular shapes may be missed. In a province like Alberta with diverse population sizes in its subregions, combining multiple subregions may lead to large geographic portions identified as a potential cluster when the actual population sizes may be relatively small. Other study limitations include our definition of a case as an adolescent with at least one ED visit for mood disorders during the study period and this definition does not include all adolescents who have a mood disorder or all adolescents who seek non-ED health services. We have also assumed that the sRHA of residence has not changed over time and that the data do follow a Poisson distribution. Furthermore, the potential clusters may be spurious because of differential distributions of key variables that are unaccounted for in the analysis (i.e., some key confounder that varies with geography), variations in
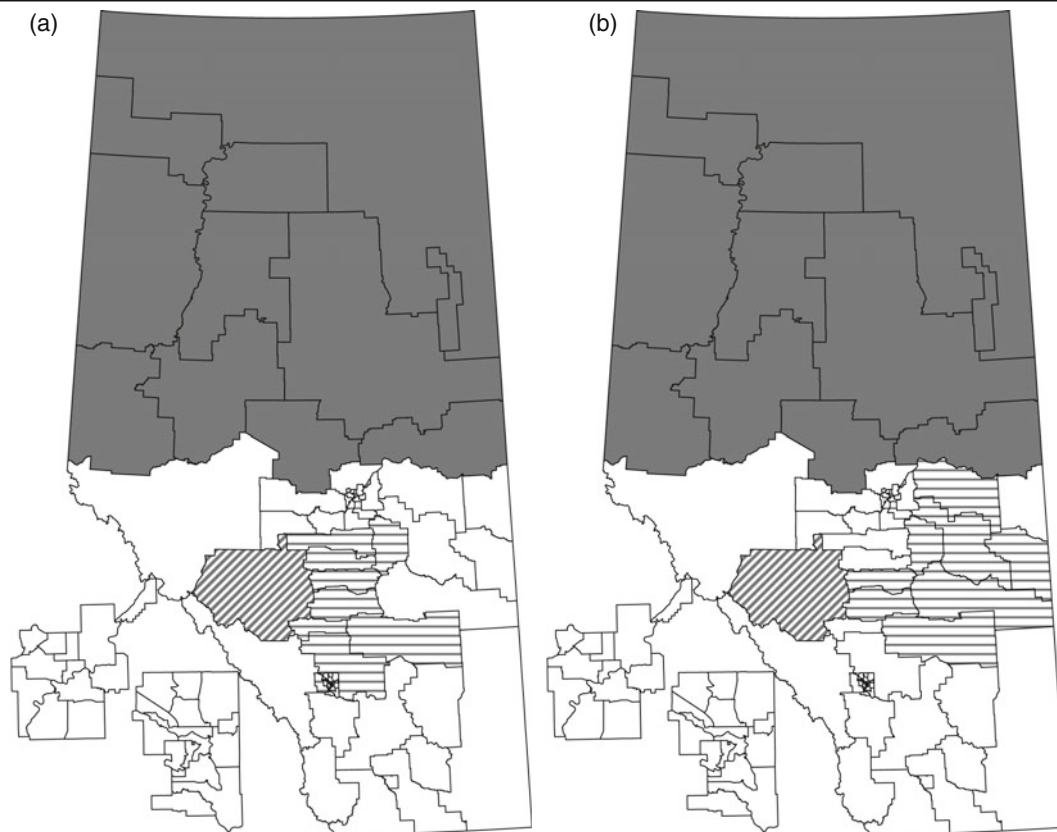
Figure 2. Clusters identified over space and time for a) adolescents with ED visits for mood disorders, and b) adolescents without a 30-day physician follow-up visit after an ED visit

For both a) and b): Cluster 1 in dark grey; Cluster 2 in diagonal lines; Cluster 3 in horizontal lines.

coding practices, or chance occurrences. Notwithstanding these limitations, our study is based on a long study period with large, population-based databases and identification of these potential clusters can lead to further targeted studies and provide areas that may benefit from the implementation of programs (e.g., education, intervention) to reduce ED use for mood disorders in adolescents.

In summary, our population-based study spanned 9 fiscal years and showed variations in the number of adolescents presenting to EDs for mood disorders and the number of adolescents presenting to EDs without 30-day physician follow-up over geography. The potential clusters identified may represent geographic areas with higher disease severity or a lower availability of non-ED health services. The clusters are not all likely to have occurred by chance and further investigation and intervention could occur to reduce ED use by adolescents with mood disorders.

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RÉSUMÉ

OBJECTIFS : Nous avons employé une technique de détection statistique des grappes de cas pour repérer les zones géographiques comportant un plus grand nombre de jeunes qui : 1) s'étaient présentés aux urgences pour un trouble de l'humeur et 2) qui n'avaient pas eu de visite de suivi en santé mentale avec un médecin dans un délai de 30 jours de leur visite aux urgences.

MÉTHODE : Nous avons mené une analyse en population des visites aux urgences (n = 6 829) effectuées par les jeunes de 10 à 17 ans (n = 5 877) en utilisant les bases de données administratives de l'Alberta, au Canada (2002–2011). Nos analyses statistiques ont porté sur les résumés, sur les taux directement standardisés (TDS p. 100 000 habitants) et sur un test de balayage spatial pour identifier les grappes.

RÉSULTATS : Les TDS rajustés selon le sexe et l'âge ont augmenté de 21,8 % entre 2002 et 2011 (160,2/100 000 à 195,1/100 000). Le nord de l'Alberta présentait des TDS systématiquement plus élevés que ceux d'autres zones de la province, et les zones du nord, du sud-ouest et du centre ont été identifiées comme ayant des grappes géographiques et temporelles avec des risques relatifs de 1,67, 2,78 et 1,42, respectivement. Beaucoup de ces zones avaient également des risques relatifs plus élevés pour les jeunes n'ayant pas visité un médecin pour des raisons de santé mentale dans un délai de 30 jours après une visite aux urgences. Environ 32 % (n = 1 870) n'avaient pas vu de médecin après leur visite aux urgences.

CONCLUSION : Les grappes potentielles repérées pourraient représenter des zones géographiques où la gravité des maladies ou la demande de soins actifs est plus élevée en raison de la moins grande disponibilité d'autres services. Les grappes ne sont pas toutes susceptibles de s'être formées aléatoirement; il est donc important pour la suite des choses de pousser la recherche et les discussions avec les responsables locaux des politiques de soins de santé en vue de réduire le nombre de visites aux urgences pour des troubles de l'humeur et d'accroître les suivis médicaux après les visites aux urgences.

MOTS CLÉS : adolescence; analyse en grappes; agrégation spatiotemporelle; agrégation de cas de maladies; service urgences; troubles de l'humeur