Synthesis Through Simulation: Insights on the Epidemiology of Mood and Anxiety Disorders in Canada

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Objective: Prevalence estimates for mood and anxiety disorders in Canada are available, but various methodological approaches have produced inconsistent results. Simulation studies involve careful examination of available data by an expert modelling team working together with subject matter experts. Simulation can integrate datasets and literature-based estimates from various sources into a coherent mathematical representation of the underlying total population epidemiology.

Methods: Supported by the Mental Health Commission of Canada, a simulation modelling project for mental disorders in Canada was recently undertaken. The modelling was carried out by RiskAnalytica using their Life at Risk platform. Specification and calibration of the model occurred in consultation with national and international experts.

Results: To reconcile estimates of incidence and prevalence, recall bias needed to be represented in the model. This suggests that the population prevalence of mood and anxiety disorders has been underestimated by population surveys and may explain a discrepancy observed in the age-specific prevalence in population surveys as compared with studies using administrative data. The number of Canadians with mood and anxiety disorders is projected to increase in upcoming decades as a result of population growth, but, based on conservative assumptions, an increased prevalence proportion is not anticipated.

Conclusions: Simulation models can act as a platform for economic analyses and epidemiologic projections and can support the rapid exploration of what-if scenarios, thereby informing policy decisions. This first national-level simulation provides a high level overview of mood and anxiety disorder epidemiology in Canada.

Objectif : Des estimations de la prévalence des troubles anxieux et de l'humeur au Canada sont disponibles, mais diverses approches méthodologiques ont produit des résultats incohérents. Les études en simulation font appel à un examen minutieux des données disponibles par une équipe experte en modélisation qui collabore avec des experts en la matière. La simulation peut intégrer des ensembles de données et des estimations fondées sur la littérature issus de sources diverses dans une représentation mathématique cohérente de l'épidémiologie sous-jacente dans la population totale.

Méthodes : Avec l’appui de la Commission de la santé mentale du Canada, un projet de modélisation par simulation pour les troubles mentaux au Canada a été récemment entrepris. La modélisation a été exécutée par RiskAnalytica, au moyen de leur plateforme Life at Risk. La spécification et le calibrage du modèle ont été effectués en consultation avec des experts nationaux et internationaux.

Résultats : Afin de concilier les estimations de l’incidence et de la prévalence, il a fallu représenter des biais de rappel dans le modèle. Cela laisse entendre que la prévalence des troubles anxieux et de l’humeur dans la population a été sous-estimée par les enquêtes auprès de la population et peut expliquer l’écart observé dans la prévalence par âge des
Despite nearly 40 years of research in psychiatric epidemiology in Canada, some basic aspects of the epidemiology of mental disorders remain poorly understood. This uncertainty is partially due to inconsistencies involving the diagnostic criteria for these disorders, the inclusion of different sets of disorders in various surveys, a preponderance of cross-sectional (as opposed to longitudinal) studies, and variability across provinces in health administrative databases. For example, Canadian surveys have generally reported that mood and anxiety disorder prevalence diminishes with age; a pattern that has not been observed in administrative data. Whereas major depression lifetime prevalence estimates in the range of 10% have generally been reported by surveys along with a low frequency of treatment, a study using Alberta administrative data found that the 3-year treated prevalence of mood disorders in the general population of Alberta was 16%. Data from developed countries participating in the World Mental Health surveys have raised the possibility that cohort effects may produce large increases in prevalence in upcoming decades. However, these findings have been disputed, as recall bias is another explanation for the same patterns in the data. Such uncertainties slow progress in epidemiologic research and leave policy-makers with an incoherent evidence base.

Inconsistencies in the epidemiologic literature could theoretically be settled by conducting long-term studies employing detailed and highly accurate measurement strategies. Until such studies are conducted in the real world, simulation offers the promise of delineating a tentative solution to these controversies. In Canada, the MHCC has advanced progress on this front by sponsoring the development of a simulation model for mental disorders.

Changes to the population and societal burden of disease caused by mental disorders, including mood and anxiety disorders, may be influenced by various factors (for example, population aging and growth). Simulation approaches are capable of representing such complex systems, including those characterized by dynamic, nonlinear relations. Simulation methods can also combine very disparate types and forms of data in a breadth that is unprecedented. For example, information from focused studies of health conditions in population groups can be combined with total population demographic, health and social service use, and disability and economic data (such as labour force statistics) to examine illness dynamics in a total societal context. Computer simulation is therefore an important research tool for health policy decision-making as there is currently no other research method with similar capabilities. Computer simulation is essentially a tool for exploring possibilities through the model’s dynamic behaviour which is, in turn governed by a set of well-defined operating rules. Simulation fills gaps left by standard research methods and unexplored research questions, allowing for better-informed decision making. It provides an opportunity to explore future possibilities, as well as to investigate the impact of different interventions through exploration of what-if scenarios.

There has been a historical reluctance for the health care sector to apply computer simulation as a research tool. Nevertheless, this appears to be changing. For example, simulation was used extensively by Smetanin et al and Stiff et al during the 2009 pandemic to better understand the ability of intensive care units to handle the widespread re-emergence of the swine-origin H1N1 influenza virus.

The current modelling initiative on mental disorders was carried out by RiskAnalytica, using a platform called Life

### Abbreviations

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<th>Abbreviation</th>
<th>Description</th>
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<tr>
<td>CCHS 1.2</td>
<td>Canadian Community Health Survey: Mental Health and Well-Being</td>
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<td>MHCC</td>
<td>Mental Health Commission of Canada</td>
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<td>SUD</td>
<td>substance use disorder</td>
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### Clinical Implications

- An internally consistent model of mood and anxiety disorders in Canada indicates that lifetime prevalence is underestimated in older populations.
- The number of Canadians with mood or anxiety disorders is expected to increase owing to population growth, particularly for people aged 70 years and older.
- The model provides a consistent framework to quantitatively evaluate the impact of potential interventions.
- These results are simulated. They are not direct epidemiologic estimates.
- Development of a baseline model was guided by a panel of subject matter experts. Erroneous interpretations could lead to inaccurate representation.
- Concise differentiation of mood and anxiety disorders was not possible.
at Risk. Development of the model incorporated direct input from the MHCC as well as a series of consultations with Canadian subject matter experts and international collaborators. The resulting base model strove to represent the epidemiology of mental disorders in the population. The model synthesizes the best available data from various sources into an internally consistent and credible representation of the epidemiology. A detailed report is available. Our objective is to report on the findings of the model through peer-reviewed literature to inform the state of knowledge of mental health of the Canadian population.

Methods
The Life at Risk platform provides a flexible, but powerful, means to model the impact of illness on the overall health and economics of a population. For the analysis of mental disorders in Canada, the Life at Risk compartmental model was used, which divides the population into a set of unique, nonoverlapping population cells. For example, at a minimum, the population is divided by age and sex. The model can then be further divided into health states. This division of population cells can continue until the required level of specificity is achieved. Once the population is divided, the rate at which people can transition between cells is defined. For example, people can transition from a younger age group to an older age group through aging, or from a healthy state to a mental disorder state through incidence. In addition to these transitions between population cells, some processes allow people from outside the model to enter into the population (that is, birth or immigration), and others remove people from the system (that is, death or emigration).

The population in our study was initially divided by demographic characteristics consisting of age, sex, and immigration status (immigrant or nonimmigrant). The population groups were then further subdivided by possible health states. Both mental illness (including SUDs) and 2 chronic medical diseases (heart disease and type II diabetes) were included in the model. Because insufficient population-based data on illnesses occurring below the age of 9 years were available, the model was based on a conservative simplifying assumption that children aged 8 years and younger had no mental illness or chronic disease. Children aged 9 to 12 years (inclusive) could have up to 5 mental illnesses, with each illness defined as active or in remission. In addition, to account for increased risk of adolescent illness for those who have had a childhood illness, the adolescent population groups were divided by previous illness. Because of the lack of longitudinal data on child and adolescent disorders in Canada, meta-analysis of data from 3 longitudinal cohort studies from New Zealand and the United States was used to estimate the transition patterns from the initial 5 disorders in childhood, through any subsequent disorder in adolescence and, in turn, from adolescent disorders through any subsequent disorder in adulthood.

The resulting base model strove to represent the impact of mental illness in Canada from a national perspective but did not include all disorders, model specific population groups, such as First Nations, Inuit, and Métis (owing to unavailability of data), or specific jurisdictions, such as provinces and territories (owing to initial decisions on scope). However, the model is capable of further specification on these or related topics if sufficiently detailed data become available.

While the modelling considered many data sources, a major challenge to producing an optimal model was the limited availability of data. Data gaps and limitations are outlined in a detailed report, and (usually conservative) assumptions used to address data are also described there in detail. These assumptions were approved by the project’s panel of subject matter experts.

The model included dementia and schizophrenia as well as childhood conditions, but the focus in our article is on mood and anxiety disorders. Major sources of mood and anxiety disorder data were the Mental Health Supplement of the Ontario Health Study (analyses of the original dataset were carried out) and a Manitoba report by Martens and the Manitoba Centre for Health Policy. The demographic data used to determine birth, death, and migration rates came from Statistics Canada. The relative risk of death associated with adult mood and anxiety disorders was taken from a meta-analysis of international studies. Incidence data for mood and anxiety disorders for the 18 to 64 year age group came from a major prospective study conducted in the Netherlands, whereas, for the 65 years and older age group, the Canadian Study of Health and Aging was a major data source. Comorbidity data for 2 categories of physical condition—heart disease and type II diabetes (both from national data sources and along with published literature)—were incorporated in the model, along with their expected effects on mood and anxiety disorder incidence and vice versa.

Analyzing data from a New Zealand birth cohort study, Moffitt et al observed that repeatedly measured annual disorder prevalence resulted in a cumulative prevalence that exceeded retrospectively assessed lifetime prevalence, an observation that has also been made in Canada. Consistent with these observations, an adjustment for recall bias was made so that mortality-corrected lifetime prevalence would increase with age in the model. The healthy immigrant effect on mental disorder prevalence was represented using findings reported by Menezes et al. A bibliography of many additional data sources may be found in the detailed report.

Several simplifying assumptions were employed. In this literature, age- and sex-stratified estimates were generally not available, thus a single sex ratio was assumed for each illness category. A single excess risk of mortality was used for each category, and this was assumed to be age- and sex-independent. Figure 1 presents a general schematic of the Life at Risk model.
Figure 1 A schematic representation of the progression of a single disease in the model

- Population without disease
- Incidence rate depending on comorbid conditions
- Population with disease
- Remission rate depending on comorbid conditions
- Population with disease in remission
- Mortality due to other causes
- Excess mortality due to the disease

Figure 2 Estimated (2011) and projected (to 2041) prevalence counts for mood and anxiety disorders, by age and sex

Figure 3 Estimated (2011) and projected (to 2041) annual prevalence proportions (%) for mood and anxiety disorders, by age and sex
Results

In an examination of administrative data from several provinces, a large degree of variability was observed in the frequencies of specific diagnostic codes for mood and anxiety disorders separately, but combined prevalence was found to be consistent across provinces. This consistency has been observed before in Canada. As a result, mood and anxiety disorders were generally modelled together, rather than as separate categories. The resulting data synthesis implicitly attributes the differing pattern of age-specific prevalence seen in Canadian surveys (prevalence generally declines with age) and Canadian administrative data (prevalence does not decline with age) to a distortion of survey results by recall bias.

In 2011, it was estimated that there are more than 4 million people living with a mood or anxiety disorder (including youth) in Canada. By 2041, the annual number of people living with a mood or anxiety disorder is expected to increase by 22.9%, reaching more than 4.9 million people or 11.4% of the total Canadian population. This increase is primarily driven by population growth and the aging population demographics.

Given the nature of the model and its underlying assumptions, annual prevalence output was considered more meaningful to report than lifetime prevalence. Figure 2 shows projections for the number of people with a mood or anxiety disorder by age and sex during the next 3 decades. Figure 3 presents similar projections for prevalence proportions. Age-specific prevalence is projected to be stable, but changing population demographics will lead to increased numbers of cases, particularly in older age categories.

The model emphasizes some of the limitations of lifetime prevalence as a population-health metric. This parameter continues to be frequently reported and an adjustment factor for recall bias is built into the model, allowing the
model to produce estimates of lifetime prevalence. Lifetime prevalence of mood and anxiety disorders in the baseline model, stratified by age and sex, is presented in Figure 4. Prevalence is seen to increase until about age 50 years, and then to level off. This contrasts with declining age-specific lifetime prevalence, as has typically been observed in population surveys. The declining annual prevalence is due to inclusion of a remission rate in the model, a rate that was calibrated for consistency with incidence, annual prevalence, and mortality data.

As mentioned above, a major use of this sort of model is to explore what-if scenarios. In the future, a detailed assessment of specific health policy options may be feasible. Here, an example of the general approach is presented. Using the calibrated base model, the impact of various intervention scenarios were evaluated to help estimate their potential impact. For example, a hypothetical intervention where the remission rates are increased by 10% would result in 259 000 fewer people living with mood and anxiety disorders by 2041. In contrast, a hypothetical intervention that reduces incidence by 10% would result in 326 000 fewer people living with mood and anxiety disorders by the same year. However, as shown in Figure 5, both hypothetical interventions are complementary and have the greatest impact in different age groups.

Discussion
This project had limitations. There are many known risk factors for mental illnesses that were not included in the modelling, such as socioeconomic status, adverse childhood events, and smoking. Owing to data and time constraints, the model only included age, sex, type II diabetes, heart disease, immigrant status, and previous (including childhood) or concurrent mental illness as risk factors. The long-term projections are therefore vulnerable to unexpected changes in various determinants of mood and anxiety disorders that were either not included in the model or where the projections (for example, immigration rates) turn out not to be true.

The detailed Life at Risk model did produce projections for mood and anxiety disorders separately. These are available in the detailed report. However, in view of the greater consistency seen in Canadian surveillance data that combines the 2 groups, the combined estimates were presented in our report. One of the main applications of simulation modelling is the projection of future costs. For interested readers, the detailed report includes cost projections for these disorders. Finally, the detailed report includes estimates for various childhood disorders, SUDs, and schizophrenia, as well as estimates of persistence of childhood and adolescent disorders into adulthood.

Estimates arising from this simulation modelling project are national in scope, but most health policy decisions in Canada are made at the provincial level. Province-specific modelling would provide a better link to policy decisions. The model can be expanded or modified in the future to accommodate new data, including province-specific data. The base model will provide a useful platform for integration of new results with well-established ones.

Psychiatric epidemiology has gone through various phases—what has been called the first, second, and third generation of studies. The third generation label is applied to large, sophisticated population surveys, which have been available in Canada from regional studies since the 1980s and nationally since the 2002 CCHS 1.2. Some believe that a next generation of studies will use large, truly population-based (that is, including the entire population) health administrative databases to overcome the limitations of survey data. RiskAnalytica did use such information in creating these estimates. However, analyses based on administrative data have their own limitations. Within the broader domain of science and technology, simulation is often viewed as a logical progression from the accrual of individual estimates from various types of studies. In a 2007 lecture, Jim Gray commented that scientists have been empirically describing natural phenomena for thousands of years, and using models to extend and generalize these observations during the past few hundred years, but the computational branch of science (using simulation to represent complex phenomena) has been an activity only of the past few decades. Simulation is an approach to data synthesis that can help to integrate available data, providing a useful representation of real-world systems. This project, the first of its kind in Canada, has provided a high-level perspective on several important issues related to the epidemiology of mood and anxiety disorders.

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