To Everything There Is a Season: Hospitalizations in Ontario Demonstrate Strong Evidence of Seasonality and Predictability

Do hospital admissions have consistent patterns? Seasonality is an important aspect of disease manifestation as well as a clue to the etiology of disease. Consistent seasonal behaviour suggests the possibility of predictable behaviour. While individual diseases are extensively studied, no studies have systematically evaluated the seasonality and predictability of hospital admissions using health services data.

Using time series analysis, seasonality in the occurrence of healthcare events was examined, including seasonal fluctuations in hospital admissions, starting initially with discrete disease categories including asthma, falls and aortic aneurysms. Subsequently, it was hypothesized and confirmed that the hospitalizations in the system considered in totality also demonstrated consistent seasonal effects (Crighton et al. 2003). Recognizing the shortcomings of several test statistics, the R2 Autoreg, interpreted similarly to a correlation coefficient, was created to measure the magnitude of seasonal effects (value of 1 = perfect seasonality; 0 = no seasonality) (Moineddin et al. 2003).

More than 6.5 million admissions representing 52 distinct disease categories over an 11-year timeframe were examined (Upshur et al. 2005). Hospital admissions were identified by ICD-9 code from the Canadian Institute for Health Information Discharge Abstract Database. Discharge diagnoses were ranked by frequency, converted to rates per 100,000 population and assessed for statistical evidence of seasonality. The R2 Autoreg values ranged from a high of 0.95 (bronchiolitis) to a low of 0.11 (infantile cataract). Fourteen categories showed evidence of strong seasonality (R2 Autoreg greater than 0.7), 28 categories showed evidence of moderate seasonality (R2 Autoreg between 0.40 and 0.69) and 10 categories showed evidence of weak seasonality (R2 Autoreg less than 0.40). Table 1 shows the complete admission series, ranked by R2 Autoreg values, and also indicates the number of predicted values falling outside the 95% confidence interval.

As expected, many of the categories falling in the strong seasonality group were related to respiratory diseases, such as bronchiolitis, croup and pneumonia, which are strongly correlated with the presence of viral pathogens, such as influenza viruses and respiratory syncytial virus. However, the highly seasonal behaviour of chronic disease, such as osteoarthritis, and surgical conditions, such as appendicitis and uterine fibroids, was unexpected. Further analysis indicated that reduced surgical volumes drive the seasonality during the summer. Of note, conditions believed to be seasonal, such as bipolar disorder and gastrointestinal bleeding, showed no evidence of seasonality.

The first 148 months of data were used to create predictive models for the final 12 months of data. The predictive models performed well: 96.5% of the predictions fell within

Table 1. Statistical summary of seasonality and predictability of hospital admission series, in Ontario, 1988–2001

Hospital Admission Series	R2Autoreg	Predicted Values Outside 95% CI*
Strong Seasonality		
Acute bronchiolitis	0.95	0
Non-infectious gastroenteritis	0.91	0
Pneumonia/influenza	0.88	0
Osteoarthritis	0.86	0
Appendicitis	0.84	0
Uterine fibroids	0.83	0
Congestive heart failure	0.82	0
Previous C-section	0.82	0
Prostatic hyperplasia	0.80	0
Singleton birth	0.76	0
Croup	0.75	0
Diverticulosis	0.75	0
Excessive menstruation	0.72	0
Chronic obstructive pulmonary disease	0.71	0
Moderate Seasonality		
Urinary tract infection	0.69	3
Coronary atherosclerosis	0.69	0
Kidney stones	0.67	0
Breast cancer	0.67	0
Myocardial infarction	0.67	1
Gall bladder	0.66	0
Prostate cancer	0.62	3
Senile cataract and cataract unspecified	0.60	0
Acute pancreatitis	0.60	0
Threatened premature labour	0.59	1
Gall bladder w/acute cholecystitis	0.57	0
Convulsions	0.54	0
Trochanteric fracture	0.53	0
Chronic tonsillitis	0.51	0
Recurrent manic depression (depressed phase)	0.51	0
Premature rupture of membrane	0.50	1
Displacement of inter-lumbar disc	0.50	1
Dehydration	0.50	2
Syncope and collapse	0.48	5
Uncomplicated diabetes	0.48	0
Lung cancer	0.46	0

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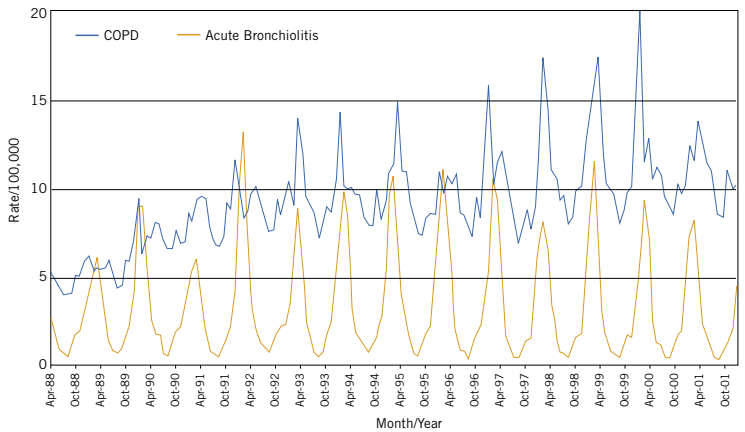
Depressive disorder	0.45	1
Fractured femur	0.44	3
Unilateral inguinal hernia	0.43	0
Abdominal pain	0.43	0
Transient cerebral ischaemia	0.41	2
Acute but ill defined cardiovascular disease	0.40	0
Angina	0.40	0
Weak Seasonality		
Unspecified intestinal obstruction	0.38	0
Other acute ischaemic heart disease	0.36	1
Recurrent manic depression (manic phase)	0.35	4
Fetal distress	0.34	0
Spontaneous abortion unspecified	0.33	0
Stroke	0.31	0
Chest pain (nonspecific)	0.29	4
Gastrointestinal bleed	0.26	0
Other ischaemic heart disease	0.17	0
Infantile cataract	0.11	0

95% CI = 95% confidence interval
Data source: Canadian Institute for Health Information – Discharge Abstract Database

Figure 1. Time plot of hospital admissions for chronic obstructive pulmonary disease and acute bronchiolitis in Ontario 1988–2001



Data source: Canadian Institutes of Health Research

the 95% confidence interval (602/624). Overall, 37 categories (37/52 = 73%) were accurately predicted for a 12-month period. Ten categories had only one observed value outside prediction limits, while four categories had two values outside 95% prediction intervals. All of the categories in the highly seasonal series were completely predictable.

Figure 1 illustrates the striking seasonal patterns of chronic obstructive pulmonary disease (COPD) and acute bronchiolitis. As is evident, respiratory diseases show striking and explosive increases over a short time period.

Ontario's hospital admissions show remarkable consistency and predictability. A heterogeneous group of health conditions was represented in the sample, including surgical and medical conditions, acute and chronic diseases, and communicable and non-communicable diseases. The performance of the proposed model for predicting the one-year ahead number of hospital admissions in Ontario is excellent for the 52 most frequent hospital admission types considered in this study.

These results are significant, as most healthcare planning is based on what could be termed the invariance principle, which holds that all events are equally likely to happen and, therefore, hospitals should be staffed and managed accordingly. This study indicates that demand for hospital services varies, and that it can be predicted with a high degree of accuracy. Thus, planning and resource allocation could be reorganized to reflect this knowledge. Furthermore, there are significant seasonal fluctuations to at least one-third of the series analyzed, indicating that planning could be tailored to predictable demands.

References

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