Methods for Measuring Life Expectancy at Birth in Toronto Neighbourhoods

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Background

Life expectancy at birth is widely used to summarize mortality in a population and to evaluate health disparities across different population subgroups. Life expectancy at birth can be interpreted as "the number of years a newborn infant would live if prevailing patterns of mortality at the time of its birth were to stay the same throughout its life." More recently, there has been interest in measuring and understanding the variability of life expectancy among city neighbourhoods. In 2014, with funding support from the Robert Wood Johnson Foundation, the Center on Society and Health at Virginia Commonwealth University developed a series of maps showing neighbourhood-level life expectancy at birth for two dozen U.S. cities. More recently, the CDC published comprehensive life expectancy estimates for most of the census tracts in the U.S. for the period 2010-2015. Such a systematic approach to estimating small-area life expectancy does not currently exist in Canada. In 2021, researchers at the University of British Columbia published life expectancy estimates at the census tract level for Metro Vancouver, using data from 1990-2016. To our knowledge, there are no estimates for life expectancy at birth in Toronto neighbourhoods for any time period.

Objective

To estimate life expectancy at birth in all 158 Toronto neighbourhoods, using mortality data from 2020 and 2021 and census population data for 2021.

Data Sources

1. Vital Statistics: Death counts for 2020 and 2021
    a. Death counts for census tracts were obtained from Vital Statistics through IntelliHealth, a data repository maintained by the Government of Ontario.
    b. For each census tract in the city of Toronto, we extracted mortality data with exact death counts, stratified by age group (0 to less than 1 year, 1-4 years, and then for 5-year intervals, ending at an open interval of 90 year or higher), sex (men, women) and calendar year (2020, 2021). Location was based on where individuals resided at the time of death.
    c. For this analysis, we considered the mean death count, by age group, sex and neighbourhood, i.e. data for years 2020 and 2021 were averaged.

2. Statistics Canada: Population data from 2021 Census

Statistics Canada provided the population counts by Toronto neighbourhoods, and by age groups and sex as described above, rounded randomly to a multiple of 5 for the 2021 census year. Random rounding is a data management practice applied by Statistics Canada to limit the risk of re-identification of individuals from statistical datasets. The 2021 census reported population counts for Men+, Women+ and Total – Gender. The plus (+) symbol indicates that non-binary persons have been distributed into the men and women gender categories.

3. Notes
   Differences in methods, in definitions, or in the time period for reporting age, sex or gender, and place of residence may not place all individuals into the same categories in both the Vital Statistics and census datasets.

Methods

a. Death counts in census tracts were aggregated up to the neighbourhood level using a crosswalk file that linked census tracts' unique identifiers to each of the 158 Toronto neighbourhoods.
b. We merged death count and population data by neighbourhood, age group and sex.
c. We adapted the Bayesian small-area statistical model in Yu et al. (2021) to estimate mortality rates.
d. Model assumptions:
    i. Separately for men and women, we can conceptualize our data as including spatio ("non-overlapping areal units": neighbourhood) and temporal ("observed over multiple time periods": age groups) information
    ii. We can assume that these spatio-temporal data are autocorrelated
    iii. We will assume that these spatio-temporal autocorrelations can be modelled according to "conditional autoregressive (CAR) priors within a hierarchical Bayesian model" framework
    iv. Separately for men and women, the model outcome is death counts in each neighbourhood and age group follow a Poisson distribution with mean equal to the age- neighbourhood-specific mortality rate multiplied by the population
    v. The model takes the general form of:
    death count=population count (offset) + (spatio-temporal autocorrelated random effects).
    vi. The spatio-temporal autocorrelated random effects are random effects for neighbourhood + random effects for age group + random effects for the interaction of age group by neighbourhood.
    vii. Each neighbourhood random effect is correlated to each other depending on the neighbourhood weight matrix (matrix 0/1, based on whether neighbourhoods "touch"
        - The exact formulas can be found at https://cran.r-project.org/web/packages/CARBayesST/vignettes/CARBayesST.pdf in the ST.CARanova() section.

e. Software R
    i. Functions and packages
        - The R package is CARBayesST using the ST.CARanova function. Additional packages sf, sp, spdep were used to process the spatio-temporal datasets
    ii. Estimation of mortality rates
        - For men and women separately, the fitted values for death counts were obtained from the model results and divided by the offset to obtain the estimated mortality rate for each age group and neighbourhood

f. Life tables and life expectancy estimation
    i. Statistics Canada guidelines for constructing life tables were adapted in order to use the model-estimated mortality rates
    ii. We adapted the guidelines to accommodate our dataset. First, we only had 2 years of mortality counts and 1 year of population data instead of 3 years for both mortality and population as in the guidelines. Second, we could not model 95 to 100, 100 to 105, 105 to 110+ since we did not actually have the death counts breakdown for those groups. We also did not use their method for death probabilities between 0 to less than 1 year since we did not have 2020 population numbers

Results and Sensitivity Analysis

Life expectancy at birth was calculated following the Statistics Canada guidelines.

a. Neighbourhood life expectancy: Life expectancy at birth was estimated separately for men and women and overall, by neighbourhood, using the model described above. We conducted a sensitivity analysis to compare the results to those obtained without the model, by dividing death counts by population, by age, sex and neighbourhood and plugging them into the life tables.

b. City-wide life expectancy: Life expectancy at birth for the city of Toronto—men, women and overall—were estimated using mortality rates estimated as death counts divided by population, and plugging them into the life tables.

References

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