**Multimorbidity, dementia and health care in older people: a population-based cohort study**

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## ABSTRACT

**Background:** Multimorbidity and dementia are key challenges for health systems worldwide and their prevalence increases with age. Little is known about how multimorbidity, dementia, and increasing age combine to influence health outcomes or utilization.

**Methods:** We did a retrospective population-based cohort study of all 610,457 adults aged ≥65 years residing in Alberta, Canada between 2002 and 2013. We used validated algorithms applied to administrative and laboratory data from the provincial health ministry to assess the presence/absence of dementia and 29 other morbidities, as well as clinical outcomes (death; emergency department visits; all-cause hospitalization) and a proxy for loss of independent living (discharge to long-term care). Cox and Poisson models were adjusted for year-varying covariates.

**Results:** Over median follow-up of 6·8 years, 153,125 (25%) participants died and 5,569 (1%) were discharged to long-term care. At baseline, the median number of conditions was 2 (range 1 to 3). The prevalence of dementia rose over time by approximately 0·2% per year from 6·2% in fiscal year 2003 to 8·3% in fiscal year 2012, representing a net increase of approximately 13,700 people. The likelihood of all clinical outcomes (death; physician claims; emergency department visits; all-cause hospitalization; discharge to a long-term care facility), increased with increasing age and with greater burden of morbidity. The presence of dementia further increased the risk of all clinical outcomes,

especially for mortality and discharge to a long-term care facility. The absolute proportion of participants discharged to a long-term care facility was 0·6, 3·3 and 12·0% for those aged 65-74, 75-84, and ≥85 years respectively; among those ≥85 years, these proportions were 1·7, 2·6 and 4·8% for those with 2, 3 or 4 morbidities but without dementia, and 28·0, 35·6 and 37·6% for those with 2, 3 or 4 morbidities as well as dementia.

**Interpretation:** Dementia acts as a risk multiplier across across all age and morbidity strata; the presence of dementia is associated with excess risk of adverse health outcomes including death and discharge to a long-term care facility. The increasing prevalences of dementia and multimorbidity over time suggest the need for coordinated national strategies aimed at mitigating the health challenges associated with the aging population.

## INTRODUCTION

Many people have multiple chronic conditions, which is termed multimorbidity.[1] Multimorbidity is common and associated with worse clinical outcomes and higher health care costs, compared to good health or to the presence of a single chronic condition.[2-5] Multimorbidity increases in parallel with age, and multimorbidity among older people is felt to be a key driver of health care costs and the sustainability of health systems worldwide.[6] Dementia is also an age-related condition that poses a major societal burden, and some evidence suggests that dementia is more common in the presence of multimorbidity.[7-11]

The prevalences of older age, multimorbidity and dementia are all projected to increase over the next few decades. However, there are major knowledge gaps concerning the basic epidemiology of multimorbidity among older people; its clinical and economic consequences; and the link between dementia, increasing age and multimorbidity[12]. It is uncertain whether higher levels of morbidity are accompanied by increasing prevalence of dementia in all age strata, and whether dementia is associated with excess risk of adverse outcomes even in the setting of multimorbidity or advanced age. It is especially important to clarify how these three inter-related factors interact to influence the capacity to live independently, which is a key outcome for patients, families and policy-makers.

We used a population-based dataset of people aged 65 years or greater and living in Alberta, a Canadian province with 4 million people, to characterize the frequency of dementia and 29 other common chronic conditions. We examined the joint associations between age, dementia, and burden of morbidity with clinical outcomes (mortality, physician visits, emergency department visits, and hospitalizations). We also aimed to describe the relationship between increasing age, dementia, multimorbidity, and loss of capacity for independent living, defined by discharge to a long-term care facility.

## METHODS

This retrospective population-based cohort study is reported according to the STROBE guidelines.[13] The institutional review boards at the Universities of Alberta and Calgary approved this study.

### *Data sources and cohort*

We used the Alberta Kidney Disease Network (AKDN) database, which incorporates data from Alberta Health (AH; the provincial health ministry) such as physician claims, hospitalizations and ambulatory care utilization; the Northern and Southern Alberta Renal Programs (NARP and SARP); and the clinical laboratories in Alberta. This database has been widely used[14-16] because of its population-based coverage of a geographically defined area, including demographic characteristics, health services utilization, and clinical outcomes. Additional information on the database is available elsewhere, including the validation of selected data elements.[17] All people registered with AH were

included in the database; all Alberta residents are eligible for insurance coverage by AH and >99% participate in coverage. The database was used to assemble a cohort of adults aged ≥65 years who resided in Alberta, Canada between May 2002 and March 2013. We followed participants from May 2002, their 65th birthday, or registration with AH (whichever was later) until March 2013, death, or migration out of the province.

*Comorbidities*

Informed by a systematic review of multimorbidity measures,[18] the Quality and Outcomes Framework of the UK General Practice contract, and health service planning by NHS Scotland, Barnett *et al* identified a set of 40 morbidities and used them to generate a comprehensive assessment of multimorbidity in the UK. We aimed to use the same set of morbidities in our work, but the Barnett study used administrative codes from NHS Scotland, which are not available in Canada. From this set, we found and published validated algorithms for 29 chronic conditions that could be applied to Canadian claims data and had positive predictive values ≥70%[19]: alcohol misuse, asthma, atrial fibrillation, lymphoma, non-metastatic cancer (breast, cervical, colorectal, pulmonary, and prostate), metastatic cancer, chronic heart failure, chronic pain, chronic obstructive pulmonary disease, chronic hepatitis B, cirrhosis, severe constipation, dementia, depression, diabetes, epilepsy, hypertension, hypothyroidism, inflammatory bowel disease, irritable bowel syndrome, multiple sclerosis, myocardial infarction, Parkinson's disease, peptic ulcer disease, peripheral vascular disease, psoriasis, rheumatoid arthritis, schizophrenia, and stroke or transient ischemic attack. Dementia

was one of the 29 conditions and was defined by the presence of 1 hospitalization or 2 physician claims within 2 years (ICD-9 290, 294·1, 331·2 or ICD-10 F00-F03, F05·1, G30, G31·1).[20] We also considered chronic kidney disease (CKD) as a 30th condition that was defined by mean annual estimated glomerular filtration rate (eGFR) <60 mL/min*1·73m$^2$ or a median annual presence of albuminuria (albumin:creatinine ratio ≥30 mg/g, protein:creatinine ratio ≥150 mg/g or dipstick proteinuria ≥ trace). Each participant was classified with respect to the presence or absence of dementia and 29 other chronic conditions for each fiscal year.[21] If a participant developed a condition considered to be permanent within a fiscal year or at any point previously (lookback extended as far as April 1994 where records were available), they were classified as having the condition for that fiscal year and every ensuing year of follow-up. Conditions not considered to be permanent, such as lymphoma, were considered to remit a fixed number of years after the last contiguous instance meeting the requirements of the algorithm. For example, lymphoma was considered to absent after five years from the date when criteria for its presence were no longer met. Detailed methods for classifying morbidity status and the specific algorithms used are found elsewhere.[19]

*Clinical outcomes*

The primary outcome was time to all-cause death. Key secondary outcomes included the rate of physician visits (primary care or specialists), the rate of emergency department (ED) visits, and the rate of hospitalizations. We also evaluated loss of capacity for independent living, which was defined by first discharge to a public or

private long-term care facility (e.g., nursing homes, auxiliary hospitals) following any hospital admission.

*Statistical analyses*

We did analyses with Stata MP 13·1 (www.stata.com) and reported baseline (first year within follow-up) descriptive statistics as counts and percentages, or medians and inter-quartile ranges, as appropriate. Spine plots (multi-variable stacked bar graphs) were used to depict mortality, discharge to long-term care, and burden of dementia by age and number of morbidities. Secular trend of prevalent dementia was assessed using an autoregressive model of order 1. Analyses were aimed at the interactions between the specific exposures of dementia, number of non-dementia morbidities, and age.

In order to examine the associations between dementia, increasing morbidity burden and age with the clinical outcomes, we used a number of models: Cox regression for mortality and long-term care placements; and generalized linear regression using the Poisson distribution with a log-link for the rates of physician claims, ED visits, and hospitalizations (all separately) and a random intercept term for participant. To meet Poisson modelling assumptions, we analyzed the doubling of events (claims, ED visits, and hospitalizations) rather than absolute increments of 1 event. Outcomes were regressed on dementia, the number of other (non-dementia) morbidities (categorized as none, 1, 2, 3, 4, and 5 or more), age (categorized as 65-74, 75-84, and ≥85 years), their 3-way interaction and all three 2-way interactions; also sex, Aboriginal status (registered

First Nations or recognized Inuit), social assistance, and rural or urban residence. All covariates were allowed to vary on a year-by-year basis. We also did additional analyses that further examined the oldest age groups categorized as 85-89, 90-95, and ≥95 years.

The requirement for 3-way interaction terms was confirmed by plotting the natural logarithm of the outcome ratio against age category for each number of morbidity groups (a separate connected line for each group) for both the dementia group and the group without dementia and checking for non-additive lines. We determined that the proportional hazard assumption was satisfied by examining plots of the log-negative-log of within-group survivorship probabilities versus log-time. For Poisson modeling, we verified that the variances approximately equaled the means. The threshold *p* for statistical significance was set at 0·05.

*Role of the funding source*

This study is based in part by data provided by Alberta Health and Alberta Health Services. The interpretation and conclusions are those of the researchers and do not represent the views of the Government of Alberta. The funders had no role in the design or analysis of this study, nor the drafting or approval of this manuscript. Neither the Government of Alberta nor Alberta Health express any opinion in relation to this study. The corresponding author has access to all the data in the study and takes responsibility for the integrity of the data and the accuracy of the data analysis.

## RESULTS

*Characteristics of study participants*

Participant flow is shown in Supplemental Figure 1. There were 610,457 participants aged 65 years or greater; median follow-up was 6·8 years (range 1 day to 10·9 years; 2% of participant out-migrated before the end of follow-up). Participants were 53% female, median age was 66 years at baseline (range 65 to 110), 1% were Aboriginal, and 15% resided in a rural location (Table 1). The median number of non-dementia morbidities was 2 (range 0 to 16); the percentage of participants with 5 or more morbidities was 9%.

The prevalence of dementia rose over time by approximately 0·2% per year from 6·2% in fiscal year 2003 to 8·3% in fiscal year 2012, representing a net increase of approximately 13,700 people. Adjustment for mean age did not attenuate the prevalence of dementia over time. For all age strata, the prevalence of dementia increased in parallel with the number of non-dementia morbidities (Figure 1).

*Unadjusted likelihood of outcomes*

During follow-up, 25% of participants died and 0·9% of all participants were discharged into long-term care. The rate of physician claims was 1,795 per 100 person-years, the rate of ED visits was 71 per 100 person-years and hospitalization rate was 24 per 100 person-years. Unadjusted rates of mortality and discharge to long-term care increased with increasing age for people with and without dementia. Unadjusted rates of physician visits, ED visits and hospitalization increased with age among people without dementia, but decreased with age among those with dementia (Supplemental Table 1).

*Adjusted likelihood of outcomes*

The likelihood of all clinical outcomes (death; physician claims; ED visits; all-cause hospitalization; discharge to a long-term care facility) tended to increase with greater burden of morbidity (Figure 2), regardless of whether dementia was present or not. The exceptions were all-cause mortality (for which there was evidence of a J-shaped relation among those with dementia: with lowest risk of death observed among those with 2-3 morbidities) and for discharge to a long-term care facility among people with dementia (the likelihood of which decreased with increasing morbidity) (Figure 2). The explanation for the J-shaped relation is unclear but we speculate that increased medical attention associated with management of relatively mild comorbidity burden helped to mitigate the mortality penalty associated with dementia per se. Mortality increased with increasing number of morbidities in participants with and without dementia even after

exclusion of morbidities such as myocardial infarction, hypertension, diabetes, and heart failure (data not shown).

The presence of dementia increased the risk of all clinical outcomes, regardless of age and level of morbidity; the excess risk was especially pronounced for mortality and for discharge to a long-term care facility (Figure 2). However, the magnitude of the excess risk for discharge to long-term care that was associated with dementia appeared to decrease with increasing age and morbidity (Table 2; Figure 2). For example, among people with no morbidities, the HRs for discharge to long-term care associated with dementia (vs no dementia) were 179·85 (127·52, 253·66), 65·57 (48·64, 88·40) and 22·00 (17·15, 28·24) among people aged 65-74, 75-84 and ≥85 years, respectively (all *p*'s<0.001). Among those aged ≥85 years, the HRs associated with dementia for discharge to long-term care among those with 1, 2 and 3 morbidities were 3·48 (3·13, 3·88), 2·29 (2·14, 2·45) and 1·63 (1·56, 1·72), respectively (all *p*'s<0.001). The magnitude of the excess risks for physician visits, ED visits or all-cause hospitalization that were associated with dementia all appeared to decrease with increasing morbidity, but were not consistently modified by age (Table 2; Figure 2). These patterns were also seen when only participants aged ≥85 years were considered (Supplemental Table 2).

In contrast to these relative trends in the prognostic importance of dementia, the absolute percentages of participants who died and of those discharged to a long-term care facility (rather than home) increased in parallel with age and number of chronic

conditions; the presence of dementia acted as a risk multiplier for both of these adverse outcomes, regardless of age or morbidity burden (Figure 3). For example, the absolute likelihood of discharge to a long-term care facility (over a 5-year period) was 0·6, 3·3 and 12·0% for those aged 65-74, 75-84, and ≥85 years respectively; among those ≥85 years, these proportions were 1·7, 2·6, 4·8 and 10·7% for those with 2, 3, 4, or ≥5 morbidities but without dementia, and 28.0, 35.6, 37.6 and 46.9% for those with 2, 3, 4, or ≥5 morbidities as well as dementia.

## INTERPRETATION

### *Main findings*

In this population-based study of more than 600,000 community-dwelling people aged 65 years and older, we examined how increasing age and burden of chronic conditions modify the association between dementia and adverse health outcomes. As previously reported, the risk of poor outcomes increases in parallel with age and the number of morbidities.[2,22] We found that the presence of dementia acted as a risk multiplier across all age and morbidity strata – leading to worse health outcomes, especially for the risks of death or discharge to a long-term care facility. Although the clinical impact of dementia is already considerable, we also found a relatively slow but consistent increase in the prevalence of dementia over time: 0·2% per year, or approximately 13,700 people per decade in Alberta. To put this statistic into context, the current capacity of Alberta's long-term care facilities is approximately 14,000 people. While not all people with dementia will lose the capacity to live independently, these findings have clear

implications for health systems and those responsible for planning and providing long-term care.

*Comparison with previous studies*

Driven by lower birth rates and longer life expectancy, the proportion of older people in the general population is steadily increasing worldwide.[7] Longer lifetimes and the potential societal benefits associated with these demographic changes are to be celebrated, but population aging also poses numerous challenges for policy-makers. Although the age-related nature of both multimorbidity and dementia are both well known, few studies have examined how the interplay between these three characteristics influence health outcomes or the capacity for independent living. Available studies demonstrate that increased morbidity burden is associated with higher prevalence and severity of dementia and cognitive impairment,[8-11,23] but are limited by relatively small sample size and lack of longitudinal follow-up for clinical outcomes or resource use. Possible explanations for the high prevalence of comorbidities in people with dementia include common risk factors (e.g., unhealthy diet), a common causal pathway (e.g., atherosclerosis), adverse effects of medications used to treat medical morbidity, or other iatrogenic factors (e.g., subclinical stroke following angioplasty for coronary disease).

The landmark House of Lords report entitled "*Ready For Aging?"* focused on the implications of the aging population for the UK during 2020–2030,[24] and singled out

dementia as an age-related condition that will require specific policy remedies aimed at prevention, management, harm reduction, and social inclusion. Our findings strongly validate this conclusion -- and suggest that there would be considerable potential benefits for national strategies on population aging generally and on the policy implications of dementia specifically. Potential areas of focus for such strategies could include health promotion (reducing the risk of dementia and other morbidities), self-care (perhaps through increased use of technology to improve function and reduce disability) tailored care for older patients with multimorbidity (accounting for interactions between conditions and the medications used to treat them, as well as side effects of medicine that are more common with increasing age), better integration between health and social care (to delay or prevent loss of independent living), and ensuring that the workforce has sufficient capacity and expertise to meet the needs of older people.[25-27]



*Strengths and limitations*

Our study has important strengths, including its use of a large population-based database from a setting with universal health care coverage, its use of validated algorithms for ascertaining the presence or absence of morbidity, and its rigorous analytical methods. However, our study also has several potential limitations that should be considered when interpreting results. First, like all studies using administrative data, residual confounding is possible by unmeasured characteristics (e.g. smoking, physical activity, and the extent of support from family members and other

caregivers), and not all data elements have been validated. Second, since participants must use medical services to be diagnosed with chronic conditions, the use of administrative data to identify morbidities will underestimate the true population burden of dementia and other morbidities. Similarly, the excess risk associated with milder forms of dementia not requiring medical attention may be less pronounced than suggested here. In addition, we did not have algorithms for certain potentially important morbidities such as osteoporosis and frailty. However, given that utilization of medical services increases with age, our focus on people aged ≥65 years at baseline should reduce the extent of such underestimation. Third, when applied to ICD-10 claims, the validated algorithm that we used for dementia has positive predictive value of 93% and sensitivity of 67%, as compared to a clinical gold standard.[20] Therefore, our findings will underestimate the true prevalence of dementia in Alberta. Fourth, our claims database only allowed us to identify people who were discharged from hospital to a long-term care facility. Since some older people enter long-term care facilities directly from home, our findings will underestimate the total percentage of people within each age stratum who eventually require long-term care. Fifth, we did not report on the incidence of dementia, because our design better captures prevalent cases; patients who develop dementia but die before they are captured as having dementia in claims data will be incorrectly omitted from estimates of dementia incidence but correctly omitted for estimates of dementia prevalence. Sixth, we studied people from a single Canadian province and our findings may not apply to other settings, although the relevant demographic and healthcare challenges are shared with all developed and

many developing countries.

*Conclusions and implications for policy and future research*

Like multimorbidity, the prevalence of dementia increases with increasing age, and age, morbidity and dementia together are strongly correlated with adverse health outcomes and a proxy for loss of independent living. These findings and the secular trends in the population prevalence of dementia suggest the need for coordinated national strategies to mitigate the health challenges associated with the aging general population. Additional research is required to determine how best to promote health, reduce disability and improve self-management in older people with multimorbidity, dementia or both.

## CONTRIBUTORS

MT and SS conceived the study. MT and NW designed the study and drafted the manuscript. NW performed the statistical analyses. All authors have made substantial contributions to the development of the manuscript, all have been involved in revising it for important intellectual content and all approved the final version. MT had full access to all of the data in the study and takes responsibility for the integrity of the data and the accuracy of the data analysis.

## DISCLOSURES

The authors have no relevant conflicts of interest.

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**Table 1. Demographic and clinical characteristics at baseline**

| Characteristic | All | Age 65-74y | | Age 75-84y | | Age 85y+ | |
|---|---|---|---|---|---|---|---|
| | | Dementia | No dementia | Dementia | No dementia | Dementia | No dementia |
| N | 610,457 | 5,424 | 435,151 | 8,652 | 115,957 | 9,772 | 35,501 |
| Male | 46.8 | 50.3 | 49.6 | 39.1 | 42.5 | 27.6 | 33.8 |
| Aboriginal | 1.4 | 3.1 | 1.6 | 0.6 | 0.6 | 0.4 | 0.5 |
| Rural | 14.8 | 13.2 | 15.7 | 10.6 | 13.3 | 10.7 | 11.8 |
| Non-dementia morbidities | 2 (1,3) | 4 (2,5) | 1 (0,3) | 3 (2,5) | 2 (1,3) | 3 (2,5) | 2 (1,4) |
| None | 23.0 | 5.5 | 25.6 | 6.7 | 17.8 | 6.6 | 19.2 |
| One | 26.3 | 12.1 | 28.0 | 13.9 | 24.8 | 13.6 | 19.5 |
| Two | 21.0 | 15.0 | 21.1 | 15.9 | 21.8 | 18.2 | 19.6 |
| Three | 13.5 | 16.9 | 12.6 | 17.1 | 15.3 | 19.0 | 15.4 |
| Four | 7.6 | 14.0 | 6.5 | 14.6 | 9.2 | 14.9 | 10.8 |
| Five or more | 8.7 | 36.6 | 6.2 | 31.8 | 11.2 | 27.7 | 15.5 |
| Alcohol misuse | 2.3 | 19.1 | 2.2 | 8.5 | 1.5 | 3.1 | 0.9 |
| Asthma | 3.0 | 6.7 | 2.7 | 5.2 | 3.5 | 4.5 | 3.6 |
| Atrial fibrillation | 6.9 | 11.9 | 4.5 | 19.5 | 10.6 | 23.4 | 15.5 |
| Cancer, lymphoma | 0.5 | 0.9 | 0.5 | 0.7 | 0.6 | 0.4 | 0.5 |
| Cancer, metastatic | 1.5 | 2.2 | 1.3 | 2.6 | 2.0 | 2.0 | 2.0 |
| Cancer, non-metastatic | 5.8 | 6.0 | 5.2 | 8.6 | 7.4 | 7.1 | 6.8 |
| Chronic heart failure | 8.7 | 20.5 | 5.1 | 28.1 | 13.3 | 37.3 | 24.1 |
| Chronic kidney disease | 18.2 | 29.3 | 17.9 | 22.8 | 16.5 | 28.0 | 21.4 |
| Chronic pain | 9.7 | 11.2 | 9.7 | 9.6 | 10.5 | 7.1 | 8.4 |
| Chronic pulmonary disease | 16.3 | 33.6 | 14.1 | 31.3 | 20.1 | 29.0 | 21.2 |
| Chronic viral hepatitis B | 0.1 | 0.2 | 0.1 | <0.1 | <0.1 | <0.1 | <0.1 |
| Cirrhosis | 0.2 | 1.3 | 0.2 | 0.4 | 0.1 | 0.1 | <0.1 |
| Constipation, severe | 1.5 | 5.7 | 0.9 | 5.7 | 2.0 | 6.2 | 3.5 |
| Depression | 7.3 | 34.5 | 6.5 | 27.2 | 6.9 | 19.5 | 6.8 |
| Diabetes | 16.8 | 29.6 | 16.8 | 23.6 | 16.6 | 17.5 | 13.1 |
| Epilepsy | 1.2 | 10.5 | 1.1 | 3.9 | 0.9 | 2.2 | 0.7 |
| Hypertension | 54.1 | 62.1 | 50.6 | 65.3 | 62.3 | 65.0 | 62.2 |
| Hypothyroidism | 11.3 | 16.3 | 10.5 | 18.0 | 12.4 | 18.8 | 13.5 |

| Characteristic | All | Age 65-74y | | Age 75-84y | | Age 85y+ | |
|---|---|---|---|---|---|---|---|
| | | Dementia | No dementia | Dementia | No dementia | Dementia | No dementia |
| Inflammatory bowel disease | 0.8 | 1.2 | 0.9 | 0.9 | 0.6 | 0.7 | 0.4 |
| Irritable bowel syndrome | 1.8 | 3.8 | 1.8 | 3.0 | 1.6 | 2.0 | 1.4 |
| Multiple sclerosis | 0.5 | 3.8 | 0.6 | 1.0 | 0.3 | 0.6 | 0.2 |
| Myocardial infarction | 4.3 | 7.9 | 3.8 | 8.0 | 5.1 | 7.2 | 5.8 |
| Parkinson's disease | 1.4 | 10.6 | 0.7 | 10.8 | 1.9 | 8.2 | 2.4 |
| Peptic ulcer disease | 0.4 | 1.5 | 0.3 | 1.6 | 0.7 | 1.2 | 0.8 |
| Peripheral vascular disease | 1.8 | 4.5 | 1.5 | 3.9 | 2.4 | 3.0 | 2.4 |
| Psoriasis | 0.7 | 1.6 | 0.7 | 0.9 | 0.6 | 0.7 | 0.5 |
| Rheumatoid arthritis | 3.0 | 5.0 | 2.6 | 4.7 | 3.7 | 4.5 | 3.7 |
| Schizophrenia | 0.9 | 16.2 | 0.7 | 6.0 | 0.4 | 3.4 | 0.3 |
| Stroke or TIA | 9.6 | 30.8 | 6.9 | 33.8 | 12.6 | 33.6 | 17.8 |

N count, TIA transient ischemic attack

Percentages and median (inter-quartile range) as appropriate.

**Table 2. Adjusted risk multiplier for dementia by age and number of morbidities**

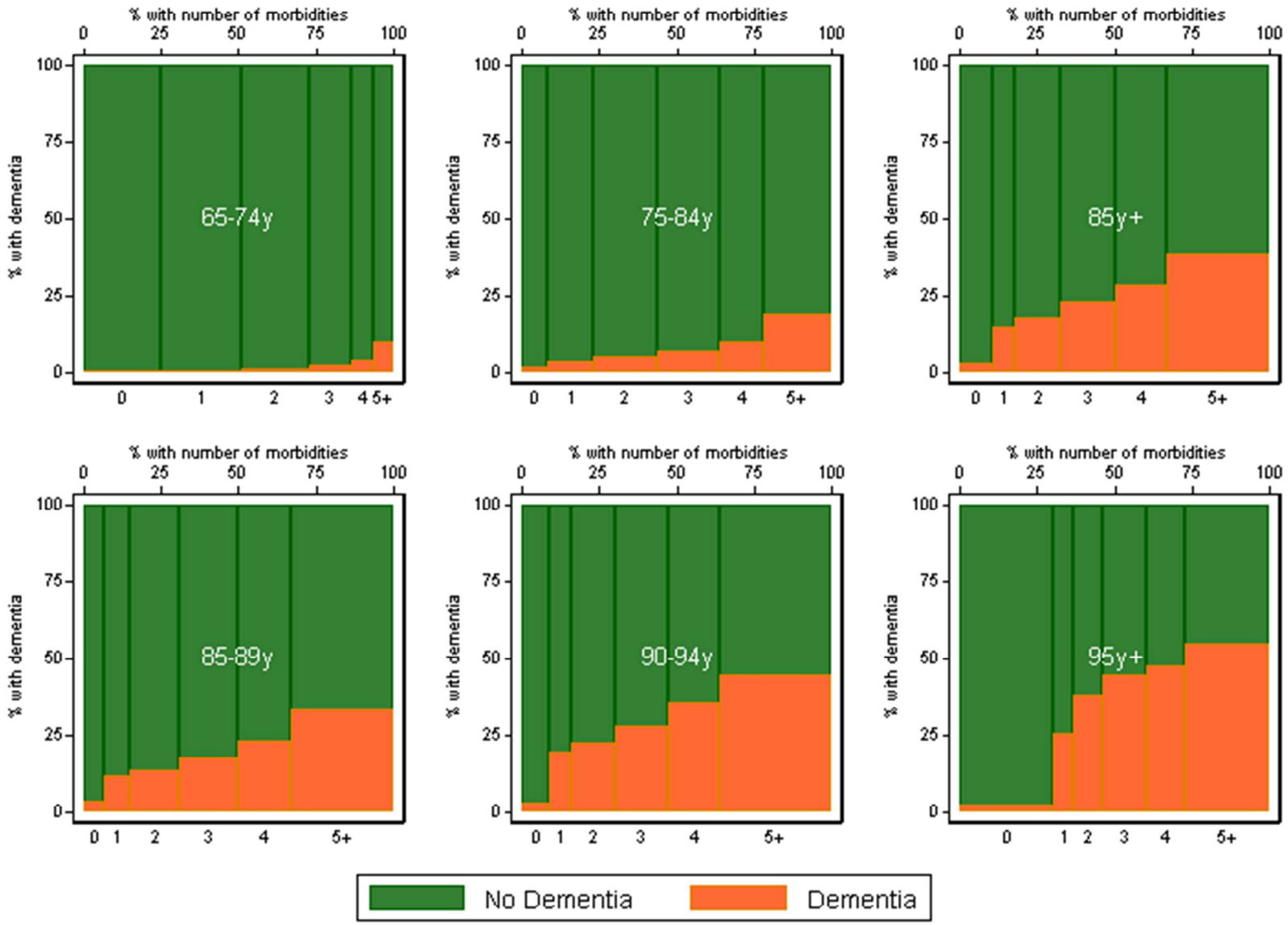
| Morbidities | No of participant-years (%) | Mortality HR (95%CI) | Physician visits RR (95%CI) | ED visits RR (95%CI) | Hospitalizations RR (95%CI) | Discharge to long-term care HR (95%CI) |
|---|---|---|---|---|---|---|
| Age 65-74y | 2,093,043 | | | | | |
| None | 409,872 (19.6) | 6.38 (5.86,6.95) | 1.79 (1.73,1.85) | 2.40 (2.14,2.70) | 5.22 (4.38,6.22) | 179.85 (127.52,253.66) |
| One | 514,511 (24.6) | 5.02 (4.74,5.31) | 1.29 (1.27,1.32) | 2.07 (1.94,2.20) | 4.02 (3.70,4.38) | 63.74 (53.52,75.91) |
| Two | 462,717 (22.1) | 4.43 (4.23,4.63) | 1.23 (1.21,1.25) | 1.93 (1.84,2.02) | 3.14 (2.95,3.33) | 28.52 (25.34,32.10) |
| Three | 320,038 (15.3) | 3.41 (3.27,3.56) | 1.21 (1.19,1.23) | 1.65 (1.59,1.71) | 2.70 (2.57,2.83) | 11.54 (10.51,12.68) |
| Four | 183,217 (8.8) | 2.55 (2.44,2.66) | 1.20 (1.18,1.22) | 1.46 (1.41,1.51) | 2.19 (2.09,2.28) | 5.41 (4.99,5.88) |
| Five or more | 202,688 (9.7) | 1.80 (1.76,1.84) | 1.20 (1.19,1.21) | 1.35 (1.33,1.38) | 1.79 (1.75,1.83) | 2.16 (2.07,2.26) |
| Age 75-84y | 1,441,821 | | | | | |
| None | 146,923 (10.2) | 4.68 (4.46,4.91) | 1.87 (1.83,1.92) | 2.80 (2.60,3.01) | 5.98 (5.36,6.67) | 65.57 (48.64,88.40) |
| One | 240,053 (16.7) | 3.66 (3.55,3.77) | 1.31 (1.29,1.32) | 1.95 (1.88,2.03) | 3.52 (3.33,3.72) | 18.20 (15.93,20.79) |
| Two | 301,412 (20.9) | 3.19 (3.12,3.27) | 1.23 (1.22,1.24) | 1.75 (1.70,1.80) | 2.99 (2.88,3.10) | 6.41 (5.94,6.92) |
| Three | 271,780 (18.9) | 2.74 (2.68,2.80) | 1.21 (1.20,1.22) | 1.54 (1.50,1.57) | 2.45 (2.38,2.53) | 3.73 (3.52,3.95) |
| Four | 191,442 (13.3) | 2.31 (2.26,2.36) | 1.20 (1.19,1.21) | 1.42 (1.39,1.45) | 2.03 (1.98,2.08) | 2.12 (2.02,2.23) |
| Five or more | 290,211 (20.1) | 1.74 (1.72,1.76) | 1.20 (1.20,1.21) | 1.27 (1.25,1.28) | 1.61 (1.59,1.63) | 1.30 (1.26,1.33) |
| Age 85y+ | 610,548 | | | | | |
| None | 70,565 (11.6) | 6.48 (6.18,6.79) | 4.48 (4.37,4.59) | 4.71 (4.33,5.12) | 10.48 (9.24,11.89) | 22.00 (17.15,28.24) |
| One | 60,779 (10.0) | 2.20 (2.13,2.26) | 1.50 (1.48,1.52) | 1.73 (1.65,1.80) | 3.12 (2.93,3.32) | 3.48 (3.13,3.88) |
| Two | 97,128 (15.9) | 2.14 (2.10,2.19) | 1.35 (1.34,1.37) | 1.48 (1.44,1.52) | 2.53 (2.44,2.63) | 2.29 (2.14,2.45) |
| Three | 107,891 (17.7) | 2.03 (1.99,2.07) | 1.30 (1.29,1.31) | 1.27 (1.25,1.30) | 2.01 (1.95,2.07) | 1.63 (1.56,1.72) |
| Four | 93,241 (15.3) | 1.85 (1.81,1.88) | 1.26 (1.25,1.27) | 1.18 (1.16,1.20) | 1.60 (1.56,1.65) | 1.26 (1.21,1.31) |
| Five or more | 180,944 (29.6) | 1.54 (1.52,1.55) | 1.23 (1.23,1.24) | 1.09 (1.07,1.10) | 1.32 (1.30,1.34) | 1.08 (1.06,1.11) |

CI confidence interval, HR hazard ratio, RR rate ratio, ED emergency department

Ratios are adjusted for sex, Aboriginal status, and rural/urban. These models include 3-way and 2-way interactions terms for dementia, age, and number of morbidity.

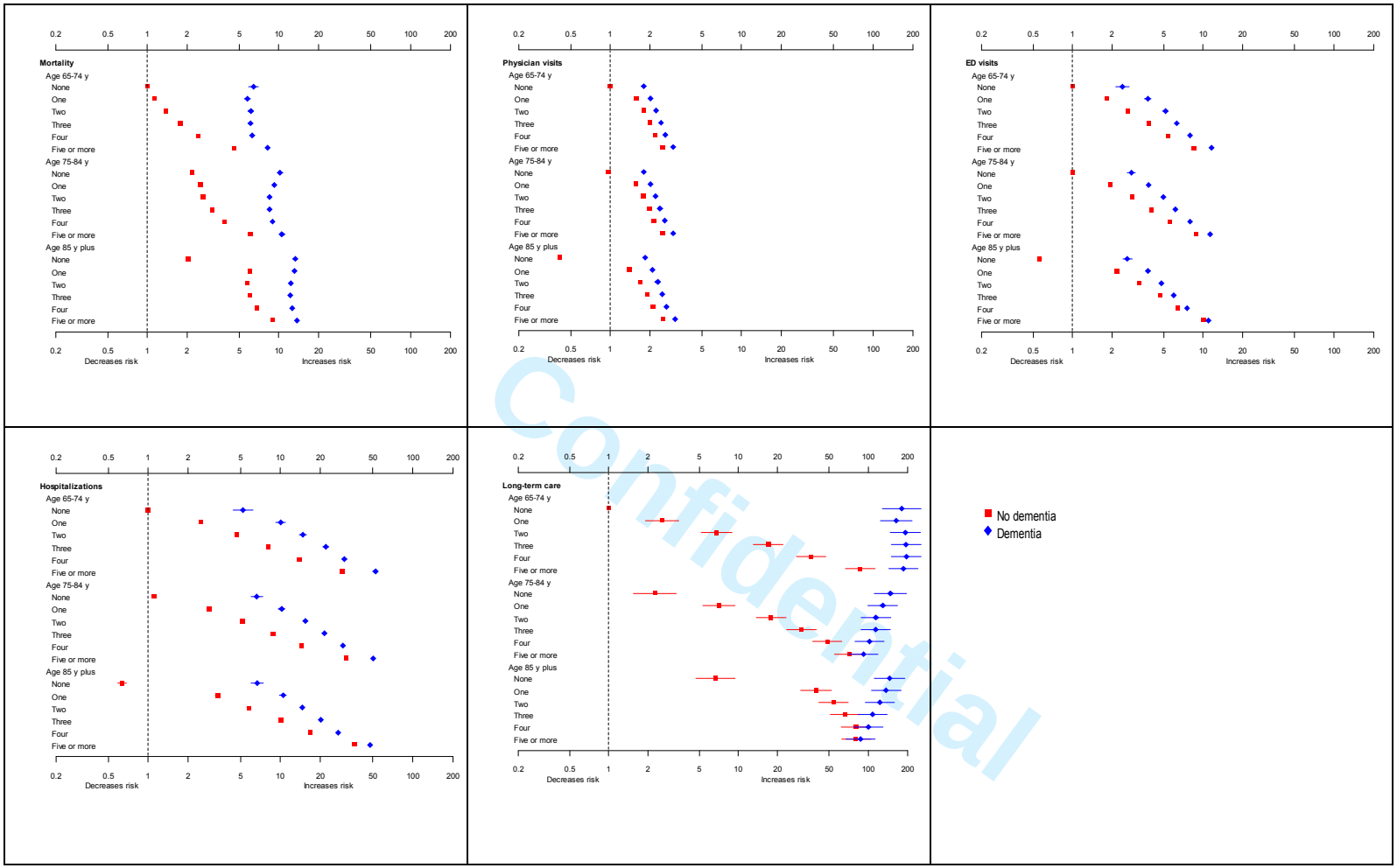
The Table shows the likelihood of a two-fold increase in the risk of the outcomes with repeat events (i.e., physician visits, ED visits, hospitalizations) that is associated with dementia, along with the risk of mortality and discharge to long-term care. For example, in those who are aged 65-74y with no comorbidities, the presence of dementia is 1.83 times more likely to be associated with a two-fold increase in the number of physician visits, compared to those of similar age and with no comorbidities, but without dementia.

**Figure 1. Relative proportion with dementia in fiscal year 2011 by age and number of morbidities**




The top row, from left to right, shows participants aged 65-74y, aged 75-84y, and age 85y+. The bottom row, from left to right, shows participants aged 85-89y, aged 90-94y, and age 95y+. Within each graph, the bars from left to right show the number of morbidities that each group has, starting at 0 morbidities and ending at 5 or more. The width of each bar shows the percentage of participants in each group. The height of each bar shows the unadjusted percentage of participants with dementia (orange), and the percentage of participants without dementia (green).

**Figure 2. Adjusted risk multiplier for number of morbidities by age and presence of dementia**



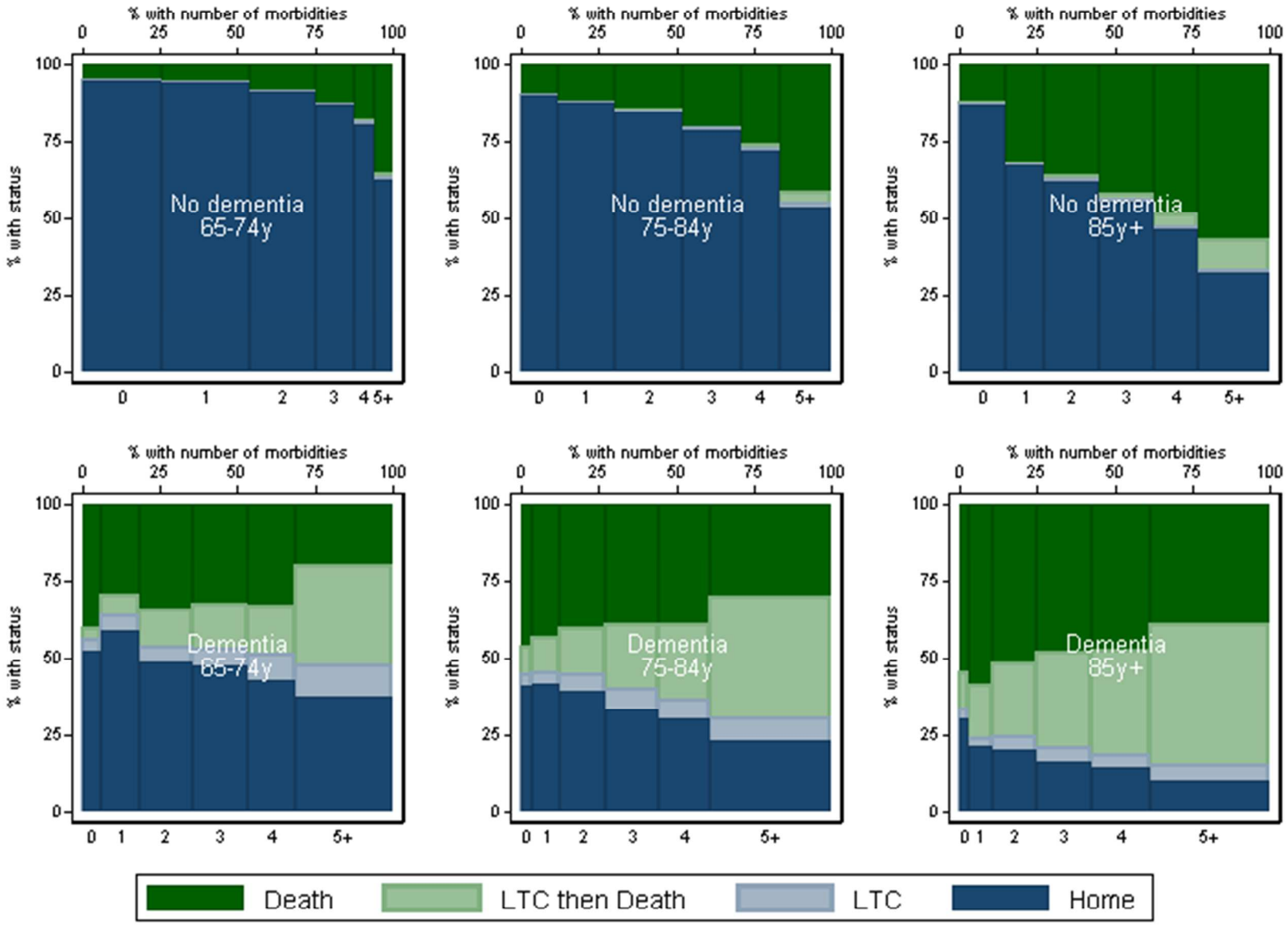



ED emergency department, LTC long-term care

The risk multipliers are presented by age, number of morbidities and dementia. They are adjusted for the number of morbidities, dementia, age, sex, Aboriginal status, and rural/urban, and are relative to people aged 65-74 years with no non-dementia morbidities. These models include 3-way and 2-way interactions terms for dementia, age, and number of morbidity. The first panel shows the hazards ratios for mortality in by the number of morbidities. The second, third, and fourth panels similarly show the rate ratios for physician visits, ED visits, and hospitalizations, respectively. The last panel shows the hazard ratios for discharge to long-term care from hospital. The blue diamond symbols show those with dementia and the red squares show those without dementia. The horizontal bars depict 95% confidence intervals.

Along with the risk of mortality and discharge to long-term care, the Figure shows the likelihood of a two-fold increase in the risk of the outcomes with repeat events (i.e., physician visits, ED visits, hospitalizations) that is associated with dementia. For example, in those, who are aged 65-74 with no dementia but one comorbidity is 1.57 times more likely to be associated with a two-fold increase in the number of physician visits, compared to those of similar age, also with no dementia but with no comorbidities.

**Figure 3. Relative proportion of deaths vs discharges to long-term facility after 5 years by age, presence/absence of dementia, and number of morbidities**




LTC long-term care

For this analysis, age and the presence/absence of dementia and other morbidities were assessed in fiscal year 2006. Clinical status (death; discharge to long-term care facility) was assessed 5 years later in fiscal year 2011. The top row shows participants with no dementia. The bottom row shows participants with dementia. The left-most column shows participants 65-74y, the middle column shows participants 75-84y, and the right-most column shows participants 85y+. Within each graph, the bars from left to right show the number of morbidities by group, starting at 0 morbidities and ending at 5 or more. The width of each bar shows the percentage of participants in each group. The height of each bar shows clinical status – the unadjusted percentage of participants that are alive without discharge to a long-term care facility (dark blue), alive but discharged to a long-term care placement after a hospitalization (light blue), deceased but discharged to a long-term care placement previously (light green), deceased and never discharged to a long-term care placement (dark green).

**Supplemental Table 1. Unadjusted event rates over follow-up**

| | All | Age 65-74y | | Age 75-84y | | Age 85y+ | |
|---|---|---|---|---|---|---|---|
| Characteristic | | Dementia | No dementia | Dementia | No dementia | Dementia | No dementia |
| N | 610,457 | 5,424 | 435,151 | 8,652 | 115,957 | 9,772 | 35,501 |
| Mortality | 21.6 | 43.6 | 10.5 | 59.6 | 22.4 | 75.7 | 39.2 |
| Physician visits | 1,795.0 | 4,890.1 | 1,393.1 | 4,404.4 | 1,795.1 | 4,318.9 | 1,845.4 |
| ED visits | 70.7 | 148.3 | 55.1 | 140.5 | 73.4 | 127.0 | 89.2 |
| Hospitalizations | 24.4 | 73.5 | 15.9 | 71.5 | 24.6 | 64.8 | 32.4 |
| Discharge to long-term care | 3.7 | 22.6 | 0.4 | 31.6 | 1.2 | 44.7 | 4.2 |

N count. Rates are per 100 person-years

ED emergency department

**Supplemental Table 2. Adjusted risk multiplier for dementia by age and number of morbidities in the oldest participants**

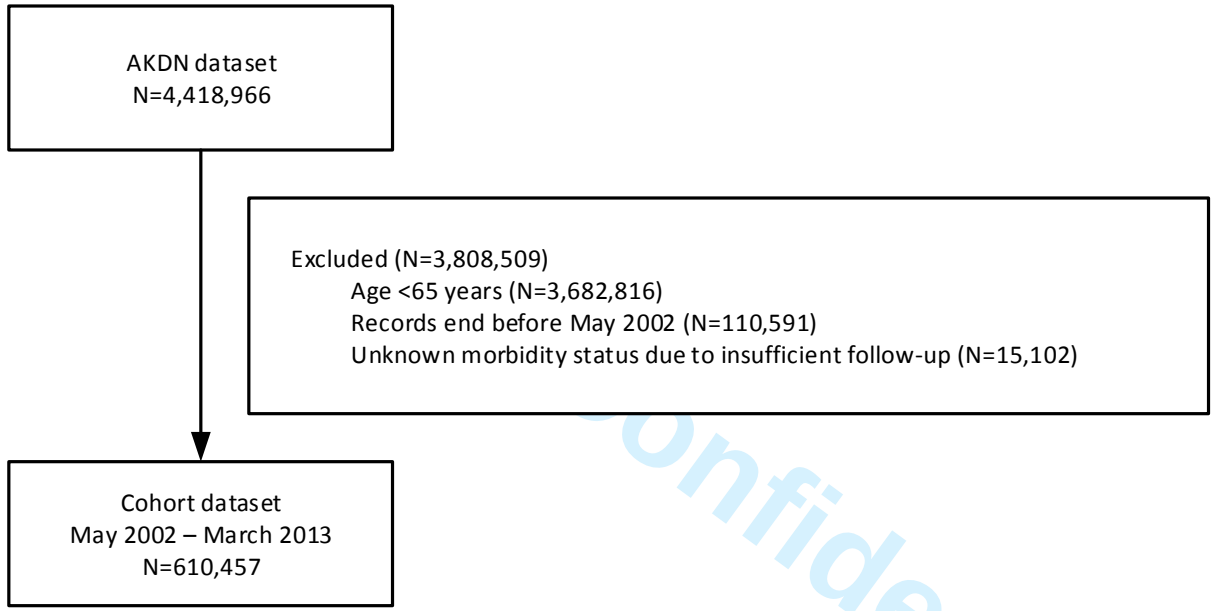
| Morbidities | No of participant-years (%) | Mortality | Physician visits | ED visits | Hospitalizations | Discharge to long-term care |
|---|---|---|---|---|---|---|
| | | HR (95%CI) | RR (95%CI) | RR (95%CI) | RR (95%CI) | HR (95%CI) |
| Age 85-89 y | 371,349 | | | | | |
| None | 31,025 (8.4) | 4.37 (4.09,4.66) | 3.47 (3.35,3.59) | 4.06 (3.64,4.52) | 7.79 (6.62,9.16) | 35.15 (24.65,50.13) |
| One | 40,346 (10.9) | 2.14 (2.06,2.23) | 1.46 (1.43,1.48) | 1.83 (1.74,1.94) | 3.29 (3.04,3.56) | 8.24 (7.00,9.69) |
| Two | 63,481 (17.1) | 2.14 (2.08,2.20) | 1.30 (1.29,1.32) | 1.63 (1.57,1.69) | 2.67 (2.54,2.81) | 4.90 (4.43,5.42) |
| Three | 68,628 (18.5) | 2.03 (1.98,2.09) | 1.25 (1.24,1.27) | 1.45 (1.41,1.49) | 2.27 (2.18,2.36) | 2.98 (2.76,3.21) |
| Four | 57,909 (15.6) | 1.87 (1.82,1.92) | 1.22 (1.20,1.23) | 1.31 (1.27,1.34) | 1.78 (1.71,1.84) | 1.86 (1.75,1.98) |
| Five or more | 109,960 (29.6) | 1.53 (1.51,1.56) | 1.21 (1.20,1.22) | 1.21 (1.19,1.23) | 1.47 (1.44,1.50) | 1.29 (1.25,1.33) |
| Age 90-94 y | 168,388 | | | | | |
| None | 18,149 (10.8) | 6.35 (5.85,6.89) | 6.05 (5.79,6.33) | 5.38 (4.66,6.22) | 12.15 (9.67,15.27) | 30.10 (19.04,47.57) |
| One | 15,026 (8.9) | 1.96 (1.87,2.06) | 1.67 (1.63,1.71) | 1.72 (1.60,1.85) | 2.94 (2.64,3.28) | 4.44 (3.69,5.35) |
| Two | 25,454 (15.1) | 1.86 (1.79,1.93) | 1.43 (1.41,1.45) | 1.44 (1.37,1.51) | 2.51 (2.35,2.68) | 2.53 (2.27,2.82) |
| Three | 29,431 (17.5) | 1.77 (1.72,1.83) | 1.34 (1.32,1.36) | 1.22 (1.17,1.26) | 1.87 (1.77,1.96) | 1.93 (1.78,2.10) |
| Four | 26,489 (15.7) | 1.64 (1.58,1.69) | 1.29 (1.28,1.31) | 1.15 (1.11,1.19) | 1.56 (1.50,1.63) | 1.40 (1.31,1.49) |
| Five or more | 53,839 (32.0) | 1.42 (1.39,1.45) | 1.24 (1.23,1.26) | 1.02 (1.00,1.04) | 1.21 (1.18,1.24) | 1.11 (1.07,1.15) |
| Age 95 y+ | 70,811 | | | | | |
| None | 21,391 (30.2) | 19.57 (17.36,22.06) | 25.60 (23.89,27.44) | 14.04 (11.17,17.65) | 26.93 (19.01,38.15) | 54.52 (31.64,93.94) |
| One | 5,407 (7.6) | 2.12 (1.97,2.29) | 2.05 (1.96,2.13) | 1.46 (1.29,1.65) | 2.21 (1.84,2.66) | 2.14 (1.72,2.67) |
| Two | 8,193 (11.6) | 1.69 (1.60,1.79) | 1.61 (1.57,1.66) | 1.15 (1.06,1.24) | 1.69 (1.50,1.89) | 1.78 (1.54,2.06) |
| Three | 9,832 (13.9) | 1.60 (1.52,1.68) | 1.45 (1.42,1.49) | 0.95 (0.89,1.01) | 1.28 (1.17,1.39) | 1.16 (1.05,1.29) |
| Four | 8,843 (12.5) | 1.40 (1.33,1.48) | 1.36 (1.33,1.39) | 0.90 (0.85,0.95) | 1.03 (0.95,1.11) | 1.04 (0.95,1.14) |
| Five or more | 17,145 (24.2) | 1.35 (1.30,1.40) | 1.29 (1.26,1.31) | 0.90 (0.87,0.93) | 1.02 (0.98,1.07) | 0.98 (0.92,1.03) |

CI confidence interval, HR hazard ratio, RR rate ratio, ED emergency department

Ratios are adjusted for sex, Aboriginal status, and rural/urban. These models include 3-way and 2-way interactions terms for dementia, age, and number of morbidities.

The Table shows the likelihood of a two-fold increase in the risk of the outcomes with repeat events (i.e., physician visits, ED visits, hospitalizations) that is associated with dementia, along with the risk of mortality and discharge to long-term care. For example, in those who are aged 85-89y with no comorbidities, the presence of dementia is 3.47 times more likely to be associated with a two-fold increase in the number of physician visits, compared to those of similar age and with no comorbidities, but without dementia.

**Supplemental Figure 1. Participant flow diagram**

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