Title: Variation in Age at First Hospital Admission for an Ageing Population: A Register Based Study of the Danish Population 1987 to 2014

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Short Abstract: Studies of health at older ages show contrasting trends between self-reported measures of chronic diseases, disability and functional limitations. Hospital admissions data provide an alternative, objective indicator for the onset of health deterioration. Average age at first hospital admission has increased over time indicating a delayed onset of health deterioration. It is not yet known known whether this has been accompanied by decreasing variation in age at admission. This reflects the WHO recommendation to measure the distribution of health. Using total population data for Denmark (1987-2014) we construct sex specific, annual period life tables for hospital admission and calculate trends in the standard deviation. Over time, a smaller proportion of people were hospitalised at younger ages alongside an larger proportion at older ages. This may indicate improvements in the health of ageing populations or improvements in preventive and community care. Examining age distributions for cause specific hospital admissions may help to disentangle this.

Variation in Age at First Hospital Admission for an Ageing Population: A Register Based Study of the Danish Population 1987 to 2014

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Structured abstract

Background: Increases in life expectancy are seen as a marker of improving population health but whether these extra years are spent in good or bad health is unclear. Empirical studies of health at older ages show contrasting trends in chronic diseases, disability and functional limitations but these findings tend to rely on self-reported measures. Hospital admissions data provide an alternative, objective indicator for the onset of health deterioration. Average age at first hospital admission has increased over time in line with average life expectancy indicating a delayed onset of health deterioration. However, the WHO have recommended that the distribution in health outcomes be measured alongside averages. It is not yet known whether increasing average age at hospital admission has been accompanied by decreases in variation in age at admission.

Methods: Individual level data on hospital admissions and population estimates for the total Danish population between 1987 and 2014 were used to construct annual period life tables and calculate trends in the standard deviation for males and females separately. The standard deviation is a measure of variability in the distribution of age at hospital admission. It reflects the mean of the weighted deviations of ages at hospital admission from the mean age at hospital admission. A 7 year wash out period was applied to remove cases of re-admission.

Findings: The age distribution of first hospital admission, conditional upon survival to age 60, has changed over time. There has been a reduction in the proportion of people being hospitalised at younger ages alongside an expansion in the distribution across older ages. The standard deviation quantified these changes. Variation in age at first hospital admission was 6.7 years for males at the beginning of the study period and 7.8 years at the end of the study period. The increase for females was 0.8 years, from 7.6 years to 8.4 years.

Interpretation: A reduction in the proportion of people experiencing a first hospital admission at younger old ages may partly reflect improvements in the health of ageing populations but it may also reflect the success of prevention and community care. We selected a definition of first hospital admission that would capture the most severe

deteriorations in health that would likely be less vulnerable to changes in admissions strategies over time. Future research could identify how the age distribution of hospital admissions has changed over time for different causes of admission. This could further help to disentangle the opposing trends between chronic disease and disability to better identify whether we live longer in good health or bad health.

Keywords: Ageing and health, hospital admission, compression of morbidity, inter-individual inequality

Background

Developed countries have progressed through the stages of the epidemiological transition and are characterised by low mortality and the presence of degenerative as opposed to infectious diseases (Omran 1971; Vallin and Meslé 2004). Subsequent gains in life expectancy, from reductions in old age mortality following on from reductions in premature mortality, are considered a marker of improving population health. However, the question remains whether these additional years are spent in good or bad health. This is of concern for both individuals and populations. Estimating the required level of pension savings, social care and medical needs of an ageing population will depend on the health status of the ageing population (Christensen et al. 2009; Lynch, Holman and Moorin 2007).

Three morbidity scenarios, that may accompany the delay in average age at death, have been proposed. Compression (Fries 1980) would be characterised by fewer years prior to death being spent in bad health because modern medicine would improve health and reduce disability and impairment. Expansion (Gruenberg 1977) suggests the extra years of life to be spent in bad health because a health decline is part of the ageing process. A Dynamic equilibrium (Manton 1982) scenario suggests that changes in mortality reflect changes in health so there is a constant balance. A large body of empirical studies have evaluated the extent to which compression, expansion or a dynamic equilibrium exist but a clear consensus has not been reached (Crimmins and Beltrán-Sánchez 2011; Lynch et al. 2007; Parker and Thorslund 2007).

Health is a multi-dimensional concept. Therefore, the reasons why some studies conclude that the number of years spent in bad health prior to death are increasing while other studies conclude the opposite are complex (Christensen et al. 2009; Crimmins and Beltrán-Sánchez 2011; Parker and Thorslund 2007). Studies tend to distinguish between measures of disease, disability and functional limitation but trends for these three dimensions of health do not follow the same patterns (Christensen et al. 2009; Crimmins and Beltrán-Sánchez 2011; Lynch et al. 2007; Parker and Thorslund 2007). While some chronic diseases show increased prevalence they may be having a reduced impact on daily living because medical interventions can slow down disease progression or the functional consequences of disease. Similarly, improving physical environments in everyday life may reduce the functional consequences of disease over time (Crimmins and Beltrán-Sánchez 2011).

One of the most common challenges surrounding the calculation of health expectancies is the reliance of on self-reported questionnaires on health status. International measures of functional limitation have been standardised which can help with international comparability but this still carries with it a risk of recall bias, selectivity and subjectivity (Parker and Thorslund 2007). Increasingly studies are utilising routinely collected data to capture objective indicators of health status.

Hospital data is one valuable source of objective data for which monitoring health status (Busse, Krauth and Schwartz 2002; Dixon et al. 2004; Hanlon et al. 1998; Oksuzyan et al. 2013; Vallgarda 1999) . Number of bed days (Busse et al. 2002; Dixon et al. 2004), number of admissions and cause of admission have all been operationalised as indicators of morbidity (Newton and Goldacre 1993; Oksuzyan et al. 2013; Simmonds et al. 2014; Vallgarda 1999). First hospital admission at older ages, as an indicator of first onset of morbidity, has also been explicitly linked to changes in life expectancy (Karampampa et al. 2013; Lynch et al. 2007).

Lynch et al. (2007) used hospital admission as an objective indicator of first chronic disabled state in order to calculate the number of years spent in a chronic disabling state or an activity limiting state. Their findings indicate that men and women lived longer in both states in 2003 than in 1980. The authors interpret this as evidence against a compression of morbidity scenario. However, they also demonstrate that average age at fist hospital admission for a chronic disability was younger in 2003 than in 1980 but was older for activity limiting conditions. A Swedish study did not distinguish between cause of hospital admission but showed that average age at hospital admission increased between 1995 and 2010 (Karampampa et al. 2013). This was interpreted as evidence of shifting in the age at first onset of severe morbidity. A limitation of these studies is that they only provide insights into changes in terms of average health.

The World Health Organistation (2000) argued that only measuring health outcomes in terms of averages overlooks important differences in the distribution across all individuals (Gakidou, Murray and Frenk 2000). Measuring only averages assumes that a homogenous gain in health has been achieved for everyone in the population or that health inequalities between individuals have stayed constant over time. The concept of inter-individual inequality has gained recent attention in the mortality inequalities literature. Less research has examined inter-individual inequality in terms of objective health outcomes. This is challenging because, unlike death, the deterioration of health is not a single, irreversible, clinically defined state. Health is partially a subjective condition that people experience in the presence and absence of disease (Arcaya, Arcaya and Subramanian 2015; Jadad and O'Grady 2008). While acknowledging this, it is still possible to measure the amount of inter-individual inequality in health. We achieve this by taking the first hospital admission as our lead indicator of health deterioration. Therefore, a key question is whether the delayed average age at fist hospital admission has been accompanied by decreasing or increasing variation in age at first hospital admission. We address this question using data covering the full resident population of Denmark between 1987 and 2014.

Data and methods

Data sources

This study uses data covering the total Danish population. We linked records from the National Patient Register (NPR) with data from the Central Population Register (CPR) using the unique personal identification number (CPR-number). The CPR includes information on the population alive and residing in Denmark since 1968, it details each resident's vital status, sex, place and date of birth. The NPR is a population-based register with nationwide coverage and contains information on all treatments provided in Danish hospitals since 1977. Data from the NPR provide a valuable tool for epidemiological research. Reporting of hospital episodes to the NPR administration are compulsory leading to high levels of completeness and reliability. We focus on overnight hospital stays. The merging of registries was carried out using Stata (version 15).

Study population

To ensure consistency in the methodology and comparability of estimated values throughout the entire study period we apply the identical procedure for each calendar year as follows. The first step is to link the CPR and NPR to match the information on all inpatient admissions and the population alive and residing in Denmark aged 60+. In the second step, we select all individuals who were admitted to hospital within the previous 7-year period – irrespective of the length of stay. These selected individuals are dropped from the analyses for the particular study year: They are neither at risk of having a first event, nor do they contribute to the number of first events. The 7-year washout period is used to ensure that first event is not a re-admission or a follow-up treatment. In the third step, we identify the population at risk at the beginning of the year and the first events. Finally, we estimate the age-specific risk of first admission $q(x,t)$ for each age $x$and each calendar year t. Age-specific risk of first admission was calculated for males and females separately. We define first events as the first inpatient hospital admission after age 60, for all causes, lasting for at least three days.

Statistical analysis

Following standard life table methods, we calculate life tables for each calendar year, for males and females separately. Using the age specific risk to have a first event at age x in year t, $q(x,t)$, we estimate $e_x hosp$. The definition of $e_x hosp$ is equivalent with the definition of e_x in a period life table: $e_x hosp$ is the remaining average number of years until the event takes place given the hospitalisation patterns of year t. In our case, $e_x hosp$ quantifies the expected average number of years until the first admission to hospital for a person who is of exact age x in year t.

Several, highly correlated, disparity indices are available (Shkolnikov and Andreev 2010; van Raalte and Caswell 2013). We measure disparity in age at hospital admission using the standard deviation, a common statistical measure of variability applied to the age

distribution in first hospital admission. In the context of this study, the standard deviation reflects the mean of the weighted deviations of ages at hospital admission from the mean age at hospital admission. A relatively higher standard deviation infers greater inter-individual inequality or more uncertainty in the timing of first hospital admission after age 60. Statistical Analysis and visualisations were carried out using R (Version 3.3.3).

Results

Figure 1 shows the age distributions of first hospital admission at the start of the study period, the mid-point of the study period, and the end of the study period.

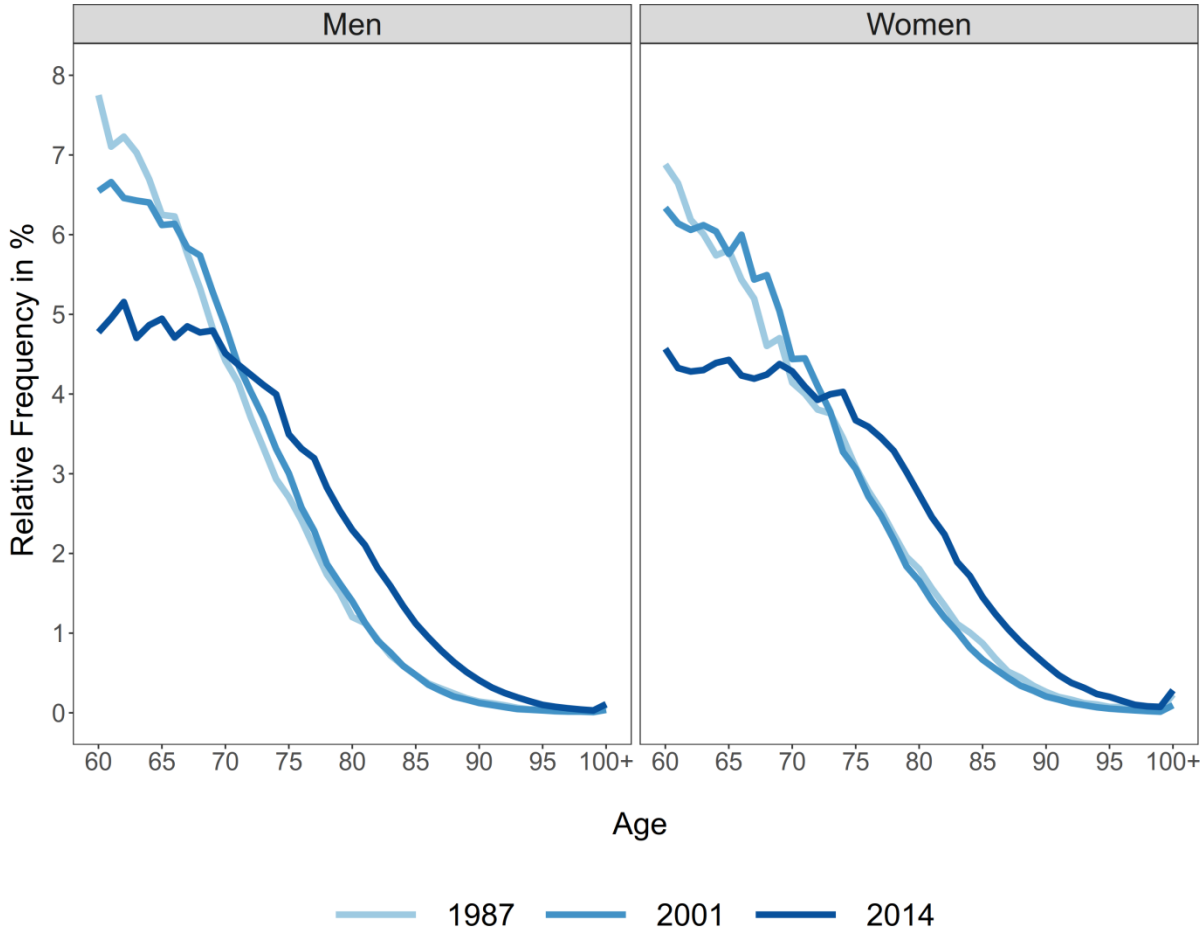

Figure 1. Age distribution of first admission to hospital for a minimum of 3 nights for all causes of admission in 1987, 2001 and 2014.

The proportion of women experiencing the first hospitalization event is lower than men at each year but over time the distributions for men and women demonstrate the same changes. Initially, there was little difference in the distributions for 1987 compared to 2001 with only a small decrease in the proportion of first hospital admissions at the younger ages.

However, by 2014 the distribution in age at first hospital admission had changed considerably. There are two changes to note.

First, across ages 60 to 70 years the proportion of individuals experiencing their first hospital admission decreased. For example, in 1987 7.8% of men aged 60 experienced a first hospitalization event. By 2014 this had decreased to 4.8%. For women in 1987 6.9% of the population aged 60 experienced a first event. By 2014 this had decreased to 4.6%.

Second, there is an increase in the proportion of the population experiencing first admission to hospital across older ages and the distribution had expanded. In 1987, only 1.2% of men aged 80 experienced a first hospital admission. By 2014 2.3% of men aged 80 experienced their first event. There was a similar increase for women aged 80 from 1.8% to 2.8%. The impact these changes in the distribution had on the level of inequality surrounding age at admission can be visualized in figure 2 which shows the trends in standard deviation for men and women.

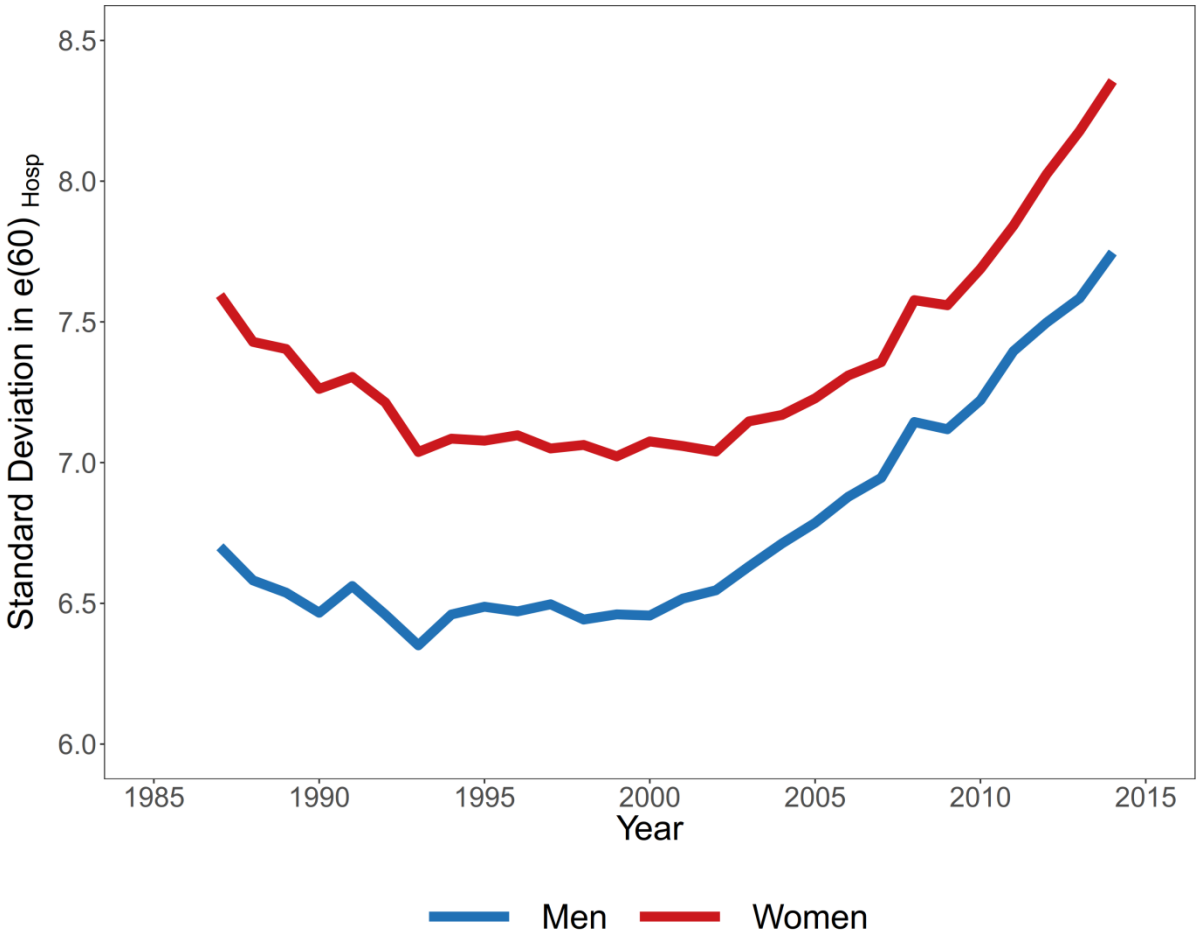

Figure 2. Standard deviation trends for age at first hospital admission, 1987 to 2014.

The standard deviation trends show that women experience greater inequality in age at hospital admission compared to men. However, both sexes demonstrate the same U-shaped trend. Inequality in age at hospital admission was decreasing at the start of the study period but changed to an increasing trend. For men, the standard deviation increased from 6.7 years in 1987 to 7.7 years in 2014. For women the increase was similar in magnitude, but in the context of higher inequality, from 7.6 years to 8.3 years.

Discussion

Interpretation of the results

The increase in the variation of first hospitalization admissions can be interpreted as a reflection of improving health – the proportion of people at younger ages being admitted is decreasing while the proportion of older people is increasing. This interpretation would be consistent to the observation highlighted by Oksuzyan et al. (2013) that treatment of the oldest patients is now more likely to be based on health status than on chronological age. However, it needs to be acknowledged that the explanations for changes in the age distribution of hospital admission are likely to be more complex than only changes in health. The changes could also be a result of greater prevention and increasing interventions to avoid unnecessary and costly hospital admissions by improved community care (Simmonds et al. 2014),or changes to hospital admissions strategies, changes to thresholds for admission, or a rise in the use of outpatient treatment. We tried to overcome some of these possible concerns by defining our first hospital admission as an inpatient stay lasting for a minimum of 3 nights. We believe that this definition is likely to capture the most severe hospital admissions that would always require inpatient care. We also used all causes of admission as it is more likely that changes in admission strategies would have a stronger effect on cause specific trends. A 7-year washout period was also consistently applied at each calendar year to remove individual cases that may relate to re-admissions.

Hospital admission data also has a number of advantages for understanding changes to population health compared with self-reported survey data. Hospital admission data are not at risk of recall bias, is routinely collected and available covering a substantial time period which is necessary for monitoring changes over time. However, monitoring population changes in hospital admissions is not a straight forward task for all populations and it is at risk of inflation if a distinction between individual patients cannot be made or if completed consultations are treated as a single admission (Capewell 1996; Luben et al. 2016; Newton and Goldacre 1993; Vallgarda 1999). Newton and Goldacre (1993) stressed that admissions or episodes of care are very different from number of patients being treated. It is also highlighted that studies of hospitalization often only begin at the point of hospitalization and population denominators are not widely available (Luben et al. 2016). Our study was

not at risk of these limitations: It covers a full population and aggregated individual level hospital admission data. Studies from the UK and Scandinavia have used linked subsamples for hospitalized populations to identify patients and distinguish multiple admissions (Busse et al. 2002; Dixon et al. 2004; Luben et al. 2016; Oksuzyan et al. 2013; Vallgarda 1999).None of these studies specifically quantified changes in the age distribution of hospital admission but all clearly demonstrated that hospital admission data is a powerful tool that can be used to construct proxy indicators for health and morbidity.

Preliminary conclusion and future steps

The ageing structure of many populations has implications for the future health care needs of the population, particularly if the years added to life are not lived in full health (Christensen et al. 2009). Existing studies have demonstrated that hospital admission data provides opportunities for monitoring changes in population health with international studies demonstrating that on average we are going to hospital later in life (Karampampa et al. 2013; Lynch et al. 2007). These summary measures are an important indicator of evolving population health, but they do not tell the whole story. We must also pay attention to how the distribution of health is changing (World Health Organistation 2000). Mortality research has begun to look at variation in age at death alongside average life expectancy but health outcomes in the living population are more challenging to estimate. Death is a single, irreversible, clinically defined state while health is more complex. We have used first admission to hospital after the age of 60 as an indicator of health deterioration to quantify how the age distribution of hospital admissions have changed over time using data covering a full population for over 25 years.

Replicating the results of our study for outpatient care or for specific cause of admission to hospital would be valuable future research. However, outpatient care admissions may be more sensitive to changes in admission strategies than inpatient admissions and outpatient data may be limited to date of visit and medical specialty (Luben et al. 2016). Inpatient hospital data gives greater insight into health of patients as they typically include at least one ICD code. Future steps will examine the age distribution of cause specific hospital admissions, using the main ICD chapters. We hypothesis that the age distribution of cardiovascular disease will have changed most during the study period.

We are currently testing the robustness of our results by (i) varying the qualifying length of first admission from 1 day to 7 days and (ii) by removing sex specific causes of hospital admission. An admission lasting at least 3 days was chosen in order to capture the most serious events that would have likely required hospital treatment consistently over the study period. Shorter durations at least partly reflect less serious conditions and medical examinations. Including sex specific admissions to hospital reflects the fact that we are interested in all-causes of admission that may indicate a deterioration in health.

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