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Rethinking Morbidity Compression: Increasing Inequality in Age at Morbidity Onset

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Key Messages

1. Morbidity compression means that years of bad health should become increasingly concentrated at the end of life. Typically, compression is measured in terms of changes in the proportion of average time spent in an unhealthy state. This approach assumes that the same average gain has been achieved for everyone, or that differences between individuals have stayed constant over time.

2. Inequality in morbidity onset across all individuals has largely been overlooked. Part of the problem is the challenge associated with estimating morbidity incidence.

3. Hospital admissions, among older ages, have been used to measure the onset of individual-level health deterioration. Routinely collected hospital admission data allow estimates of incidence of overall morbidity at the population level, from which variation in age at onset can be calculated.

4. We show that, on average, morbidity has been postponed towards older ages. Alongside this, variation between individuals has increased, suggesting that population health is becoming more heterogeneous.

5. Monitoring variation in age at morbidity onset is important for planning pensions, social care, and health services which will have to adapt to the heterogeneous needs of ageing populations, something that average morbidity measures cannot identify.

Abstract

Background: To evaluate morbidity compression, studies typically report the proportion of life expectancy spent in an unhealthy state. This overlooks variation in age at morbidity onset between individuals, a factor Fries (1980) saw as crucial for determining whether the continuation of disease postponement was possible. We use incidence of first hospitalization after age 60 to study variation in morbidity onset over a 27-year period in Denmark.

Methods: Number of hospitalizations and the population at risk for each year between 1987 and 2014 were identified using nationwide registry data. Sex-specific life tables were constructed, from which the mean and the coefficient of variation in age at first admission were calculated.

Results: Mean age at first admission increased between 1987 and 2014 from 67.8 years (95% CI: 67.7 – 67.9) to 69.5 years (95% CI: 69.4 – 69.6) in men, and 69.1 (95% CI: 69.1 – 69.2) to 70.5 years (95% CI: 70.4 – 70.6) in women. In the same period, the coefficient of variation in age at first admission increased from 9.1% (95% CI: 9.0 – 9.1) to 9.9% (95% CI: 9.8 -10.0) among men and from 10.3% (95% CI: 10.2 – 10.4) to 10.6% (95% CI: 10.5 – 10.6) among women.

Conclusions: On average, morbidity has been postponed but variation in age at onset has increased. This variation has important implications for individual life planning and population-level welfare. Pensions, social and health care services will have to adapt to an increasingly heterogeneous ageing population, a phenomenon that trends in the measurement of average morbidity onset cannot identify.

Background

Remaining life expectancy at age 60 has rapidly increased across developed countries(1). Whether the extra years of life are spent in good or bad health remains unclear, and depends in part on how health is measured(2-7). Fries (1980) proposed a scenario where 'the amount of disability can decrease as morbidity is compressed into the shorter span between the increasing age at onset of disability and death'(8). Gruenberg (1987) was more pessimistic, arguing that technological advancement would allow people to live for longer but in a prolonged state of poor health(9). Manton (1982) suggested that falling mortality rates would be associated with a change in the distribution of disease types(10). Specifically, an increase in the proportion of years spent with moderate health conditions and a decrease in the proportion of years spent with serious health conditions. Monitoring the rate of change in disability-free life expectancy (DFLE) or healthy life expectancy (HLE) compared with the rate of change in mortality is assumed to be the best way to evaluate which scenario might be emerging as populations are ageing(11-14). If gains in DFLE or HLE are greater than gains in average life expectancy, morbidity compression is likely. If gains in average life expectancy are greater, it would be considered as evidence of expansion.

Key to Fries (1980) theory of morbidity compression is that alongside increasing age at death, the years spent with bad health or disability would become increasingly concentrated at the end of life. This implies that population age distributions of morbidity would become increasingly homogenous among individuals. However, this important piece of information for determining whether the continuation of disease postponement is possible, has been overlooked in the morbidity compression debate(15). Therefore, it is not known whether improving average health has been accompanied by decreasing or increasing variation in the age of morbidity onset between all individuals. Changes in the age distribution of morbidity onset have individual-level and population-level implications beyond theory. For individuals, it represents the amount of uncertainty in the timing of health deterioration. At the macro level, pensions, social care, and health services will have to adapt to the heterogeneous needs of ageing populations, something that average measures cannot identify(16).

To estimate the age distribution of morbidity onset across all individuals, we need to distinguish between incidence and prevalence(7). Estimating incidence is challenging from cross-sectional health surveys(11). Administrative healthcare data provide an opportunity and are continuously updated. Number of hospital days, number of admissions, and cause of admission have been operationalized to

capture health(17-24). In this paper, we quantify changes in the age distribution of morbidity onset across all individuals aged 60+ between 1987 and 2014, using first hospital admission for all causes among Danish men and women. Denmark is a valuable case study country because the ageing population structure is comparable to many other developed countries. Unique to Denmark is that data exist for constructing individual-level hospitalization trajectories for the total population covering a substantial period of time(25, 26).

Methods and Materials

Data Sources

We used individual-level register data covering the total Danish population aged 60+. 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 NPR, a population-based register, contains information on all treatments provided in Danish hospitals since 1977. Reporting of hospital admissions is compulsory, leading to high levels of completeness and reliability. The CPR includes socio-demographic information on the population alive and residing in Denmark since 1968, including sex, place and date of birth, and date of death(25, 27).

Study Population

In an ideal scenario we would have health information for all individuals, covering the entire life course. This would have allowed us to identify every entry into, and every recovery from, an unhealthy state. As hospitalization data for Denmark began in 1977, we cannot identify admissions before this year. Therefore, we created an identical cohort study population for each calendar year by consistently applying the same method for each year between 1987 (to allow for a washout period) and 2014. This approach means that all estimated values were comparable throughout the study period. Figure 1 summarizes the process of identifying the study population in 1987 as an example year.

First, we linked CPR and NPR information on all inpatient admissions and the population alive and residing in Denmark aged 60+. Second, we identified all individuals hospitalized within the previous 7-year period – irrespective of length of stay, and excluded these individuals from the analyses for the particular year. Guided by existing literature(28, 29), a 7-year washout period was used to limit the chance that a first event is a readmission or a follow-up treatment. Third, for the remaining Danes we identified the population at risk and the first events within each calendar year. We defined first events

as the first inpatient hospitalization after age 60, from all causes, lasting for at least two days. We included all fatal events regardless of length of admission. This definition is likely to capture hospital admissions that would require inpatient care consistently throughout the study period. Events were included regardless of whether the outcome was death or discharge. Trends over time in the number of individuals at risk, first events, and those excluded in the washout period are given in appendix 1.

Statistical Analysis

From the number of first hospital admissions and the population at risk, we estimated the age-specific risks of first admission ($q_{x,t}hosp$), for each age x and each calendar year t. Age-specific risks of first admission were calculated for men and women separately. We constructed life tables for each calendar year using standard demographic methodology(30). Using the age-specific risks to have a first event at age x in year t ($q_{x,t}hosp$), we estimated $e_{x,t}hosp$, which is conditional upon survival to age 60. The definition of $e_{x,t}hosp$ is equivalent to the definition of remaining life expectancy at age x in year t ($e_{x,t}$) in a period life table. It quantifies the remaining average number of years until the event takes place for an individual of exact age x, given hospitalisation patterns of year t. In our case, $e_{x,t}hosp$ quantified the expected average number of years until the first hospital admission for a person who is aged x in year t. Adding 60 to the value of $e_{x,t}hosp$ allowed the interpretation to be mean age at first hospital admission lasting for a minimum of 2 days, including cases that ended in death or discharge.

We measured between individual variation in age at first hospital admission using the coefficient of variation (CoefV) and reported values as a percentage. The CoefV is a standard measure of dispersion and is defined as the ratio of the standard deviation to the mean. Here, the CoefV reflects the variability in age at first hospital admission relative to the mean age at first hospital admission. We calculated 95% Confidence Intervals (95% CI) for $e_{x,t}hosp$ and CoefV (31).

Results

Trends in Mean Age

Figure 2 shows trends in mean age at first admission. The trend demonstrates a subtle u-shaped pattern between 1987 and 2014. The trend declined in the 1990s before rebounding in the 2000s. In 1987, the mean age at first admission for men was 67.8 years (95% CI: 67.7 – 67.9). At the midpoint, 2001, mean age had increased slightly to 67.9 years (95% CI: 67.8 – 67.9). By 2014, mean age at first admission had

increased to 69.5 years (95% CI: 69.4 – 69.6). For women, the mean age decreased slightly between 1987 and 2001: from 69.1 years (95% CI: 69.1 – 69.2) to 68.5 years (95% CI: 68.4 – 68.6). By 2014, mean age for women had increased to 70.5 years (95% CI: 70.4 – 70.6).

Changes to the Age Distribution

Figure 3 shows the age distribution of first hospital admission in 1987, 2001 and 2014. We focus on the change in the distribution of first events from the age groups 60-69 to age 70+, the age groups surrounding the mean age at first admission. In 1987, 69.6% of all men experienced their first admission to hospital between age 60 and 69, while 30.4% of all men had their first admission at ages 70+. By 2001, the proportion among men aged 60 to 69 remained similar at 69.0%, before decreasing to 58.8% in 2014. Among women, the proportion who experienced a first admission at age 60-69 was 61.8% in 1987, while 38.1% experienced a first admission at ages 70+. In contrast to men, the proportion of women aged 60-69 who experienced a first admission in 2001 increased to 65.1%. By 2014, 53.3% of women aged 60 to 69 experienced a first admission and 46.7% experienced a first admission at ages 70+.

Trends in the Coefficient of Variation

To quantify changes in the age distribution, we estimated the CoefV. As shown in Figure 4, we found a u-shaped pattern. Among men, the CoefV in average age at first admission at age 60 decreased from 9.1% (95% CI: 9.0 – 9.1) in 1987 to 8.7% (95% CI: 8.6 – 8.7) in 2001. For women, the corresponding change was from 10.3% (95% CI: 10.2 – 10.4) to 9.4% (95% CI: 9.4 – 9.5). In the early 2000s, the trends in variation changed to increasing. In 2014, the CoefV was 9.9% (95% CI: 9.8 – 10.0) for men and 10.6% (95% CI: 10.5 – 10.6) for women.

Sensitivity

Our main results reflect hospital stays lasting a minimum of 2 days, including all fatal events. The direction of the trends were consistent in three sensitivity tests. First, we varied the minimum length of stay from 2 days to 1 day, 3 days, 5 days and 7 days. Second, we excluded fatal cases that occurred between the 1st day of admission and the minimum length of stay. Third, we changed the washout period length from 7 years to 5 years and 10 years. Results for sensitivity checks and further details are given in appendix 2 and appendix 3.

Discussion

Summary of Findings

Average age at first admission at age 60 was higher in 2014 than in 1987. The number of first admissions at ages 60-69 reduced during this period. These findings indicate that people became healthier across these ages. However, the shifting of events towards older ages meant that the age distribution of first hospital admission widened over time, causing the coefficient of variation to increase. In pragmatic terms, higher variation in age at first hospital admission after age 60 translates into greater uncertainty for individuals in the timing of the onset of morbidity. At the macro level, it indicates that population health is becoming increasingly heterogeneous.

Interpretations and Implications

Many people are ageing with better health today than in the past. Healthy ageing is due to multiple life course factors, including improved health during childhood, reduced exposure to hazardous working conditions, and changes in health behaviors such as smoking or diet(32, 33). Another contributing factor is that technological advancement has enabled more individuals to survive longer in better health. Although some chronic diseases may show increased prevalence over time (e.g. diabetes) they may now lead to a hospital admission later in life. Perhaps the strongest example of this, is the treatment of hypertension and cardiovascular diseases (34). Treatment has changed dramatically over time and mortality has declined, leading to more people surviving without serious cardiovascular events and only being admitted to hospital later in life. This observation is consistent with our results showing the redistribution of first events from younger to older ages.

At the same time our results show increasing diversity in healthy aging. The same technological advancements that have postponed major health events have also enabled individuals to live for longer while managing chronic conditions(9, 35, 36). Greater variation between individuals in age at first hospital admission could therefore be due to more heterogeneous health profiles arising from an increased prevalence of chronic conditions. Additionally, some component of increasing health variation could have its roots in the changing epidemiologic environment experienced by older adults as infants and children. As infectious diseases became increasingly controlled, weaker individuals that would have died as children in previous decades survived to older ages, making for a more heterogeneous population at older ages(36). Our results for morbidity echo findings for mortality which have shown

that increased survivorship has been accompanied by increasing population-level heterogeneity in age at death at these older ages(15, 36).

Methodological Considerations

Linked hospital admission data have been used to investigate health at older ages and across multiple countries(17-19). Studies clearly demonstrated that these data can be used to derive powerful indicators of health. A particular strength of our study is that we were able to identify individual patient trajectories to derive incidence-based estimates(7, 26). We used the most accurate population denominators for those at risk of admission. Other countries may only be able identify prevalence-based measures, based on the number of admissions and using an inaccurate total population denominator. Our data allowed us to identify all events during the study period and determine the exact age at event for all individuals. Studies using survey data are often restricted to picking up events retrospectively and may miss out events. While standardized, self-reported measures are powerful, there are limitations in terms of recall bias, selectivity, and subjectivity.

We attempted to exclude readmissions to hospital by applying a 7-year washout period at each calendar year. While a 7-year washout period will not fully remove all cases of readmission, it was a length of time that reflected established choices in the existing clinical research literature(28, 29). Accounting for the impact of population-level changes in admission strategies is challenging. To address this issue, we obtained an overview of admissions using 19 causes of admission for the entire study period by utilizing harmonized ICD-8 and ICD-10 codes (Appendix 4). While the relative contribution from some causes decreased over the study period, other causes increased or remained stable. Studying a change in admission strategy requires consistent, detailed information on inpatient, outpatient, and primary health care attendances by cause of admission and length of treatment. In Denmark, outpatient data and primary health care data do not contain suitable information for carrying out such analyses.

A major aim of current health care strategies is to reduce length of stay. This is driven by the assumption that shorter stays are more cost effective. We investigated the potential impact of changing the minimum length of stay on our results by repeating all stages of the analyses for hospital stays lasting for at least 1 day, 3 days, 5 days, and 7 days (Appendix 2). We found a stepwise increase in the mean and the variation in the age at first admission with every increase in minimum length of stay, but no change in the trend direction. Patients in Denmark in 2015 stayed in hospital for an average of 5.5 days,

this is one of the shortest average lengths of stay in hospital within Europe(37). Our main results define an admission as lasting for a minimum of 2 days which is likely to capture conditions that would always require inpatient care over the entire study period and does not bias the trends that are documented.

Concluding Theoretical Reflections

Studies of morbidity compression have consistently calculated the average proportion of time spent in an unhealthy state, relative to average length of life(5, 38-42). This only reflects part of Fries' theory of morbidity compression. To understand whether the continuation of disease postponement is possible 'analysis of variation, not of mean values, becomes crucial'(8). Although, it has been forty years since Fries linked the measurement of the standard deviation between individuals to the concept of morbidity compression, empirical measurement of variation has been overlooked. In this study, we measure variation in the age of morbidity onset between all individuals, using first hospital admission at ages 60 and older. Measuring the age distribution of morbidity onset across all individuals underlines that the concept of morbidity compression is more nuanced than has previously been conceived. Incorporating a variation perspective into morbidity studies is important for individual life planning and population-level welfare. Pensions, social care and health services will have to adapt to the heterogeneous needs of ageing populations, something that average morbidity measures cannot identify.

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