SSM - Population Health 12 (2020) 100692

Contents lists available at ScienceDirect

SSM - Population Health

journal homepage: http://www.elsevier.com/locate/ssmph

# Social policies and change in education-related disparities in mortality in Japan, 2000–2010

Megumi Kasajima *, Hideki Hashimoto

*Department of Health and Social Behavior, School of Public Health, The University of Tokyo, Bunkyo-ku, Tokyo, Japan*

ARTICLE INFO

*Keywords:*
Socioeconomic inequality in mortality
Absolute and relative inequality
Deterministic data linkage
Repeated cross-sectional design
Theory of fundamental causes
Japan

ABSTRACT

Persistent socioeconomic disparity in mortality is a widely observed phenomenon despite improvements in the economic standard of living and the prevailing universal healthcare coverage policy. In this study, we selected Japan as a case in which public universal coverage has maintained horizontal equity in healthcare access while demographic and economic challenges have affected the life chances of vulnerable subpopulations over the past decade. We assessed the changing trends in the education-related disparity in mortality over a decade across demographic subpopulations for different causes of death, with the goal of generating social policy lessons to contribute to closing the mortality gap. Using a deterministic data merge between nationwide census and death records, we estimated age- and sex-specific mortality rates for 14 causes and their education-related gradients with absolute and relative indices of inequality in 2000 and 2010 via Poisson regression. Estimation parameters were standardized to the age structure of the sub-population of high school graduates in 2000 as the reference. The results demonstrated that the relative gaps in all-cause mortality persisted despite a decrease in the average mortality rate over the study period. The absolute gaps in mortality increased for preventable causes of death associated with lifestyle behavior choices. The average mortality worsened among socioeconomically vulnerable populations such as youth and women, who were left behind in the existing social/economic policy. External causes of death such as suicide and traffic accidents showed decreasing absolute gaps in a subpopulation targeted by universal social and labor policy measures. These change patterns indicate that, compared with a high-risk approach, a universal policy approach to dealing with societal and fundamental causes of health inequality seems more effective in reducing the education-related mortality gap in both absolute and relative terms.

## Introduction

Persistent disparity in mortality by socioeconomic status is a widely observed phenomenon in European countries, the United States, and some Asian countries, despite improvements in the economic standard of living and the prevailing universal healthcare coverage policy in the past few decades (Chiang, 1999; Kohler et al., 2008; Mackenbach, 2012; Mackenbach et al., 2008, 2015; Marmot, 2005; Montez et al., 2011). Previous studies in European countries have suggested that preventable causes of death such as cardiovascular diseases and cancers related to lifestyle risk factors have become more likely to be susceptible to a widening gap in mortality in recent decades, presumably because behavioral choice is now a more influential factor for mortality differences by socioeconomic status (Mackenbach, 2012; Mackenbach et al., 2008, 2015), whereas average mortality has likely declined, in part because of improvements in the medical treatment of these conditions over time (Mackenbach et al., 2017). Because the countries included in these previous studies varied in terms of their healthcare systems, demographic and socioeconomic structures, and policy reactions to social inequality in health, it is difficult to determine which types of policies are effective in reducing the disparity in mortality. A single-country case study may provide a window through which to view the detailed policy implications embedded in a specific socio-politico-economic context.

Thus, in this study, we selected Japan as a case because it has maintained a high level of equality and financial affordability in healthcare while experiencing widening socioeconomic disparity caused by demographic and economic challenges from 2000 to 2010 (Sakamoto et al., 2018). Therefore, focusing on Japan in the present study enabled us to examine a case in which social policies—rather than healthcare system performance—would affect changes in the socioeconomic gap in

* Corresponding author. Department of Health and Social Behavior, School of Public Health, the University of Tokyo, Bldg. 3, 7-3-1, Hongo, Bunkyo-ku, Tokyo, 1130033, Japan.

*E-mail address:* megumi-kasajima@umin.ac.jp (M. Kasajima).

https://doi.org/10.1016/j.ssmph.2020.100692
Received 23 July 2020; Received in revised form 26 September 2020; Accepted 3 November 2020
Available online 7 November 2020

mortality.

The assessment of mortality disparity uses relative and absolute measures (Mackenbach et al., 1997). Recent trends in mortality decline generally suggest a widening gap in relative terms, although the gap may still be closing in absolute terms. The question of which measure should be adopted and prioritized in policy discussions has been a subject of debate (Mackenbach, 2015). Most recently, Blakely and colleagues proposed adopting two measures simultaneously to summarize the mortality disparity and to better visualize the policy targets for disparity reduction (Blakely et al., 2017).

In the present study, following the compass analogy of Blakely et al. (Blakely et al., 2017), we analyzed the trend change in mortality disparity for various causes of death in both absolute and relative terms using nationwide data on Japan from 2000 to 2010. This time period was characterized by a long-term economic recession and global economic shock, with policy changes related to issues such as the prevention of suicide and traffic accidents, as well as the introduction of a mass health checkup policy for all citizens, specifically aimed at addressing problems such as metabolic syndrome. These health and social policies were expected to differentially affect the risk profiles of different subpopulations. For example, a recent labor policy to expand irregular work contracts in Japan could widen the gap in suicide mortality among unskilled young people with low levels of education because of economic insecurity, while not necessarily having the same effect among older men, who tend to be protected by the newly implemented occupational hygiene measures for mental health among middle career workers. Thus, mapping the potentially different patterns in disparity trends by age group, sex, and cause of death in the specific policy context of Japan would allow us to qualitatively and interpretatively analyze plausible associations between a policy intervention and changes in inequality in relevant health conditions among the subpopulations targeted by that policy. In this way, we aimed to provide policy lessons with the potential to contribute to closing the mortality gap between groups with different levels of educational attainment.

## Methods

### *Educational attainment as an indicator of socioeconomic status in assessing the health disparity in Japan*

Previous studies describing health disparities have adopted educational attainment as an indicator of socioeconomic status because it reflects an individual's social, human, and cultural capital (Abel & Frohlich, 2012). Because it is fixed in the early stages of life, educational attainment is a relatively stable attribute over the course of one's life (Mackenbach et al., 2015; Montez et al., 2011).

However, educational attainment requires careful comparison across periods, countries, and sexes because the associations of education with income and labor class may differ according to these conditions (Goldthorpe, 2014). In 1907, Japan established a 6-year compulsory education system that covered more than 96% of eligible children regardless of sex. Compulsory education was extended to 9 years in 1947. Thus, those aged over 75 years in 2010 were educated under the earlier 6-year system (Ministry of Education, 1981).

Most studies on the change trends in the education-related gap in mortality have been conducted in European countries or the United States (Huisman et al., 2005; Kohler et al., 2008; Mackenbach et al., 2008, 2015), where individual information on educational attainment was readily available on death certificates or could be linked with mortality records using a unique identifier (Krueger et al., 2015; Mackenbach et al., 2015; Rogers et al., 2010; Ross et al., 2012). Although several cohort studies on education-related disparities in mortality have been conducted in Japan (Fujino et al., 2002, 2005; Honjo et al., 2012; Ito et al., 2008; Kagamimori et al., 2009; Kimura et al., 2016), no previous nationwide population studies have been conducted because of the lack of individual information on educational attainment in existing official death records.

In New Zealand, researchers have addressed a similar data limitation by creating a probabilistic data linkage between census data and mortality data, without a unique identifier (Blakely et al., 2008, 2013; Teng et al., 2017). As described below, in this study, we essentially followed this strategy to link census data, which include educational attainment information, to death records, using link variables that are available in both data sources.

## Data sources

### *Population census*

The Japan Ministry of Internal Affairs and Communications conducts a population census in October every 5 years. Information on educational attainment is collected in half of the census survey years. We used the 2000 and 2010 census data with educational attainment information. The response rate was 98.3% in 2000 and 91.2% in 2010 (Koike & Yamauchi, 2014). We limited our study population to people of Japanese nationality living in Japan because educational attainment may not be comparable across different countries of origin. The percentage of foreign residents in the total population of Japan was 1.26% in 2000 and 1.63% in 2010 (Ministry of Justice, 2017).

Respondent's sex, month and year of birth, address in terms of census mesh block (with two digits for the prefecture and three digits for the city), and marital status were available as candidate linkage variables. We categorized educational attainment into five groups: (i) primary or junior high school; (ii) high school; (iii) junior college or vocational school; (iv) university or graduate school; and (v) other.

### *Death records*

Individual death records including the main cause of death coded with *International Classification of Diseases, 10*th *Revision* codes were available for all individuals living in Japan at the time of their death. These records were collected by the Ministry of Health, Labour and Welfare. We used records from November 1, 2000, to April 30, 2001, and from November 1, 2010, to April 30, 2011. We limited these periods to 6 months after the October collection of the census survey in 2000 and 2010 because we expected that limited numbers of individuals moved in/out of geographic regions over such a short period.

As mentioned above, each respondent's sex, date of birth, address in terms of the city code (with two digits for the prefecture and three digits for the city), and marital status were available for linkage. We excluded three prefectures (Miyagi, Iwate, and Fukushima) from our analysis in 2010 to avoid detecting effects of the Great East Japan Earthquake on March 11, 2011, which heavily affected these areas and had a death toll of more than 15,000 people.

### *Ethical considerations*

Microdata for the census and death records were obtained with official approval from the appropriate ministry offices. Because of the anonymous nature of the data, the requirements for ethical approval and informed consent were waived for the use of these governmental microdata.

### *Census–mortality linkage*

In New Zealand, using census mesh blocks and date of birth as linkage variables, probabilistic data linkage was conducted to determine individual mortality cases matched with high probability to census cases, considering the chance of false negative matching (Blakely & Salmond, 2002). Unlike New Zealand's census, Japan's census data include only the month and year of birth, without the specific day, and death records in Japan include only the city code, rather than codes for smaller census mesh blocks. We also had to simplify marital status into two groups (currently married or not married) to match the information granularity between the census and death records. Consequently, we had to use rough segments of link variables to link the data sources, leading to a high frequency of 1:N matching within the same matching-probability segment. Because the strict use of probabilistic linkage for 1:1 matching would have resulted in a large loss of information, we chose to link the mortality and census records by deterministic linkage, with the key variables of sex, month and year of birth, prefecture, city, and marital status averaging out the educational attainment information of the N matched census cases to allow 1:N matching. For example, if a mortality record was linked with 100 census records, of which educational attainment was high school for 50, junior college for 30, and university for 20, we counted the deceased individual as contributing as a high school graduate for 50%, a junior college graduate for 30%, and a university graduate for 20%. In other words, the death count contribution of this individual was counted as 0.5 in the high school education category, 0.3 in the junior college category, and 0.2 in the university category.

### *Measurements of the mortality disparity*

Following previous recommendations, we adopted three measurements to describe the trend change in the mortality disparity: average mortality rate, slope index of inequality (SII) as an indicator of absolute disparity, and relative index of inequality (RII) as an indicator of relative disparity (Blakely et al., 2017). The original Kunst–Mackenbach slope and relative indices of inequality assume linear gradients across socioeconomic statuses (Mackenbach et al., 1997). However, linear models may provide a biased estimation of RII and SII when the gradient does not increase or decrease monotonically from the best socioeconomic position to the worst (Kjellsson et al., 2015). Therefore, Moreno-Betancur et al. proposed a new approach, estimating RII and SII by fitting log-linear regressions such as Poisson regression (Moreno-Betancur et al., 2015). In this study, we analyzed educational gradients in mortality risk following the approach by Moreno-Betancur et al. Because the majority of the results showed a linear trend, however, we present RII and SII by comparing the estimated mortality rates between the lowest (less than high school) and highest (university graduate or higher) education categories. When we observed a non-linear trend by educational gradient, we specifically mention this finding in the results section.

### *Estimation of age- and sex-adjusted mortality by educational attainment*

For the Poisson regression analysis, we calculated the expected number of deaths by educational attainment level for each prefecture, 5-year-age category, and sex. We then stratified the data into three age groups: 20–39 years, 40–74 years, and 75 years and older. For each age stratum, we calculated all-cause mortality as well as 14 disease-specific mortality rates, following the classification of mortality causes presented by Mackenbach (Mackenbach et al., 2015). We used person-years, calculated as the population in each segment for matching multiplied by half a year, as an offset. The Poisson regression analysis was conducted separately for men and women.

To precisely describe the change in the average mortality rates and in the education-related disparity in mortality from 2000 to 2010, it was necessary to account for drastic changes between these years in the age structure and in the educational attainment composition of each age stratum. To make the estimated indices comparable across years, we standardized the Poisson estimation parameters by the inverse probability weight based on the age structure of the sub-population of high school graduates in 2000 as the reference population.

### *Typology of change trends in mortality disparity*

Using the compass analogy of Blakely et al. (Blakely et al., 2017), we set the change in average mortality rates from 2000 to 2010 as the x-axis and the change of SII as the y-axis to visualize the direction of change in mortality and the education–mortality gradient over the study period. For example, if the average mortality rate was lower in 2010 than in 2000, the point would be located on the left-hand (or west) part of the map. If absolute inequality decreased over this period, the point would be located toward the south. Drawing on the terminology of Blakely et al., "going southwest" is taken as the most desirable change because the mortality gap narrows and mortality decreases. "Going northwest/west" is seen as equivocal because the disparity has not been solved despite a decline in average mortality. Finally, "going northeast" is regarded as an undesirable change.

## Results

Table 1 shows the total analytical sample, presenting the proportions of major causes of death, the distribution of education strata, and age groups by sex in 2000 and 2010. Table 2 presents the distribution of

**Table 1**
Descriptive statistics of census–mortality linkage data in 2000 and 2010.

| | 2000 census survey | | 2010 census survey | |
|---|---|---|---|---|
| | Men | Women | Men | Women |
| Total study population | 48,356,340 | 51,672,439 | 47,081,967 | 50,845,833 |
| Age structure (%) | | | | |
| 20–39 years old | 36.2% | 32.8% | 31.7% | 28.4% |
| 40–74 years old | 57.0% | 55.7% | 57.4% | 55.0% |
| 75+ years old | 6.8% | 11.5% | 11.0% | 16.5% |
| Education structure (%) | | | | |
| Less than high school | 21.5% | 24.9% | 14.5% | 16.9% |
| High school | 42.5% | 45.5% | 37.8% | 40.6% |
| Junior college/ vocational school | 7.1% | 17.3% | 7.5% | 18.5% |
| University or higher | 24.7% | 8.7% | 27.2% | 11.9% |
| Other, including unknown | 4.1% | 3.6% | 13.0% | 12.1% |
| Total number of deaths per year | 537,886 | 456,184 | 641,366 | 579,336 |
| Percentage distribution of causes of death* | 268,943 | 228,092 | 320,683 | 289,668 |
| Stomach cancer | 6.0% | 3.9% | 4.9% | 2.8% |
| Colorectal cancer | 3.7% | 3.5% | 3.6% | 3.4% |
| Liver cancer | 4.4% | 2.3% | 3.2% | 1.8% |
| Tracheal, bronchial, or lung cancer | 7.3% | 3.2% | 7.5% | 3.2% |
| Breast cancer | 0.0% | 2.1% | 0.0% | 2.1% |
| Cervical cancer | | 0.5% | | 0.4% |
| Prostate cancer | 1.4% | | 1.6% | |
| Ischemic heart disease | 7.9% | 8.0% | 7.4% | 6.6% |
| Cerebrovascular disease | 12.4% | 16.1% | 9.5% | 11.2% |
| Pneumonia/ influenza | 8.9% | 9.0% | 10.4% | 10.0% |
| Alcohol abuse | 0.8% | 0.2% | 0.8% | 0.2% |
| Road traffic accident | 1.4% | 0.8% | 0.6% | 0.4% |
| Accidental fall | 0.7% | 0.6% | 0.7% | 0.6% |
| Suicide | 3.9% | 1.8% | 2.8% | 1.4% |

* We used *International Classification of Diseases, 10*th *Revision* codes to identify cause of death: stomach cancer (C16); colorectal cancer (C18–C21); liver cancer (C22.0, C22.1, C22.9); tracheal, bronchial, or lung cancer (C33–C34); breast cancer (C50); cervical cancer (C53); prostate cancer (C61); ischemic heart disease (I20–I25); cerebrovascular disease (I60–I69); pneumonia/influenza (J10–J18); alcohol abuse (F10, I42.6, K70, K85–K86.0, X45); road traffic accident (V01–V89, Y85); accidental fall (W00–W19); and suicide (X60–X84, Y87.0).

**Table 2**
Frequency of match between census records and death records in 2000 and 2010.

| Year | 2000 | | | Number of matched death records | 2010 | | |
|---|---|---|---|---|---|---|---|
| Number of matched death records | Number of matched observations in the census | | | | Number of matched observations in the census | | |
| | ≤10 | >10 and ≤30 | >30 | | ≤10 | >10 and ≤30 | >30 |
| 1 | 198,126 (47.5%) | 81,180 (19.4%) | 79,761 (19.1%) | 1 | 164,338 (35.0%) | 107,324 (22.9%) | 101,587 (21.7%) |
| 2 | 11,668 (2.8%) | 13,438 (3.2%) | 19,152 (4.6%) | 2 | 16,488 (3.5%) | 22,864 (4.9%) | 28,082 (6.0%) |
| ≥3 | 1044 (0.3%) | 3585 (0.9%) | 9616 (2.3%) | ≥3 | 2151 (0.5%) | 7932 (1.7%) | 18,186 (3.9%) |

matching in the data linkage between death records and census data. In total, 98.1% of the death records in 2000 and 99.0% of those in 2010 were successfully linked to at least one observation in the census data for the corresponding year. Among the death records linked to the census data, 42,820 deaths (8.5% of the total number of deaths in 2000) and 27,660 deaths (4.5% of the deaths in 2010) were uniquely identified with one corresponding census record. The other death records were linked with multiple census observations. In 2000, 47.4% of the death records were linked with 1:1–10 matching to observations in the census data. In 2010, 35.0% of the death records were linked to census records with 1:1–10 matching. Larger numbers of death records were linked with more than 10 or more than 30 observations in the census data. In metropolitan areas, there was a larger portion of 1:> 30 matching than was observed in rural prefectures. The maximum number of linked census observations was seen in 20-year-old men in Tokyo in 2000, for whom death records were linked to census records with 1:883 matching. To account for prefectural differences in the matching distribution, we included prefecture as a fixed effect in the Poisson regression analysis estimating age-standardized mortality.

We present the detailed results of the estimated age-standardized mortality distribution in the appendix. To visually summarize the changes in average mortality and the inequality index from 2000 to 2010, we present a series of compass maps of the estimated changes.

Fig. 1 shows the changes in the average mortality and SII of the highest and lowest education strata for all-cause mortality by age group and sex. All population segments showed a decreasing trend in all-cause mortality from 2000 to 2010. Except among those aged 20–39 years, SII increased from 2000 to 2010 for both men and women, which resulted in the points being located in the upper left quadrant ("northwest"). In the youngest age category, the inequality index decreased from 2000 to 2010 (the lower left quadrant; "southwest"). A significant and unique finding was that, among men aged 75 years and older in 2000, the highest education strata showed relatively high mortality, which resulted in a U-shaped association between all-cause mortality and educational attainment (Appendix Fig. 1).

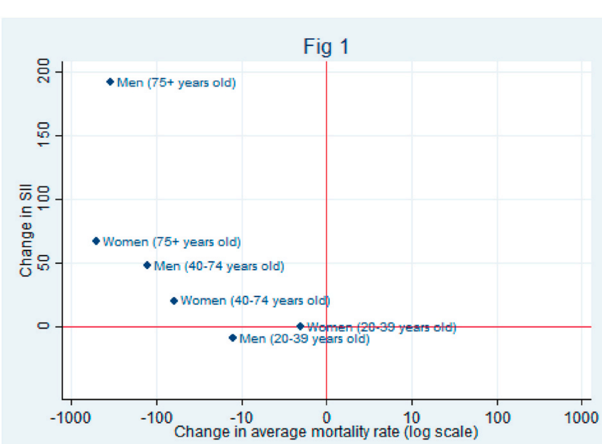



**Fig. 1.** Change from 2000 to 2010 in average mortality and slope index of inequality for all causes of death for men and women.

Figs. 2 and 3 show the change from 2000 to 2010 in the age-standardized, condition-specific mortality rates and the SII of the highest and lowest education strata for internal causes of death. The majority of the disease categories were located in the upper left quadrant, indicating improved average mortality with increased absolute inequality across educational strata. However, several exceptions were observed. First, cerebrovascular disease was located in the lower left quadrant for both men and women aged 75 years and over, and stomach cancer was located in the lower left quadrant for the 40–74 year age group in both sexes; both of these findings suggest improved average mortality with decreased inequality ("southwest"). Second, among women, average mortality from lung cancer worsened with improved inequality among those aged 75 years and over, and with widened inequality among middle-aged women. Finally, among men, the oldest age group showed worsened average mortality from both prostate cancer and liver cancer with widened inequality ("northeast").

Fig. 4 shows the change from 2000 to 2010 in average mortality rates and SII for breast cancer and cervical cancer among women. In contrast to the results for the other types of cancer presented in Fig. 3, average mortality from breast cancer worsened over this time period, except among the youngest age group, and inequality across education strata widened among middle-aged women. In 2000, we found higher mortality from breast cancer among women with higher education than among those with primary or secondary education. The education gradient was then flat in 2010 (Appendix Fig. 6). Notably, among the youngest age group, average mortality from cervical cancer worsened and there was a slight increase in educational disparity.

Finally, Fig. 5 shows the change in average mortality and SII for external causes of death. The change pattern varied by cause of death, sex, and age category. Death by traffic accident was located in the lower left quadrant, except among men aged 75 years and over. Death by accidental fall was also located in the lower left quadrant except among men aged 75 years and over. Among men, death related to alcohol abuse was located in the upper right quadrant, corresponding to worsened mortality and widened disparity. Suicide death was located in the lower left quadrant for both men and women aged 75 years and over, whereas suicide death among middle-aged men was located in the upper left quadrant. Suicide death among middle-aged women exhibited little change over the study period, whereas the youngest age group (20–39 years) showed worsened mortality for both sexes, with widened disparity among women and with decreased disparity among men.

## Discussion

We confirmed that all-cause mortality, on average, was reduced from 2000 to 2010, implying the overall success of the public health and social policies in Japan. However, consistent with the findings of Mackenbach et al. (2015), most subpopulations exhibited reductions in all-cause and cause-specific mortality rates on average, but with widening gaps. The persistent and significant education-related gradients in mortality were especially noticeable for preventable

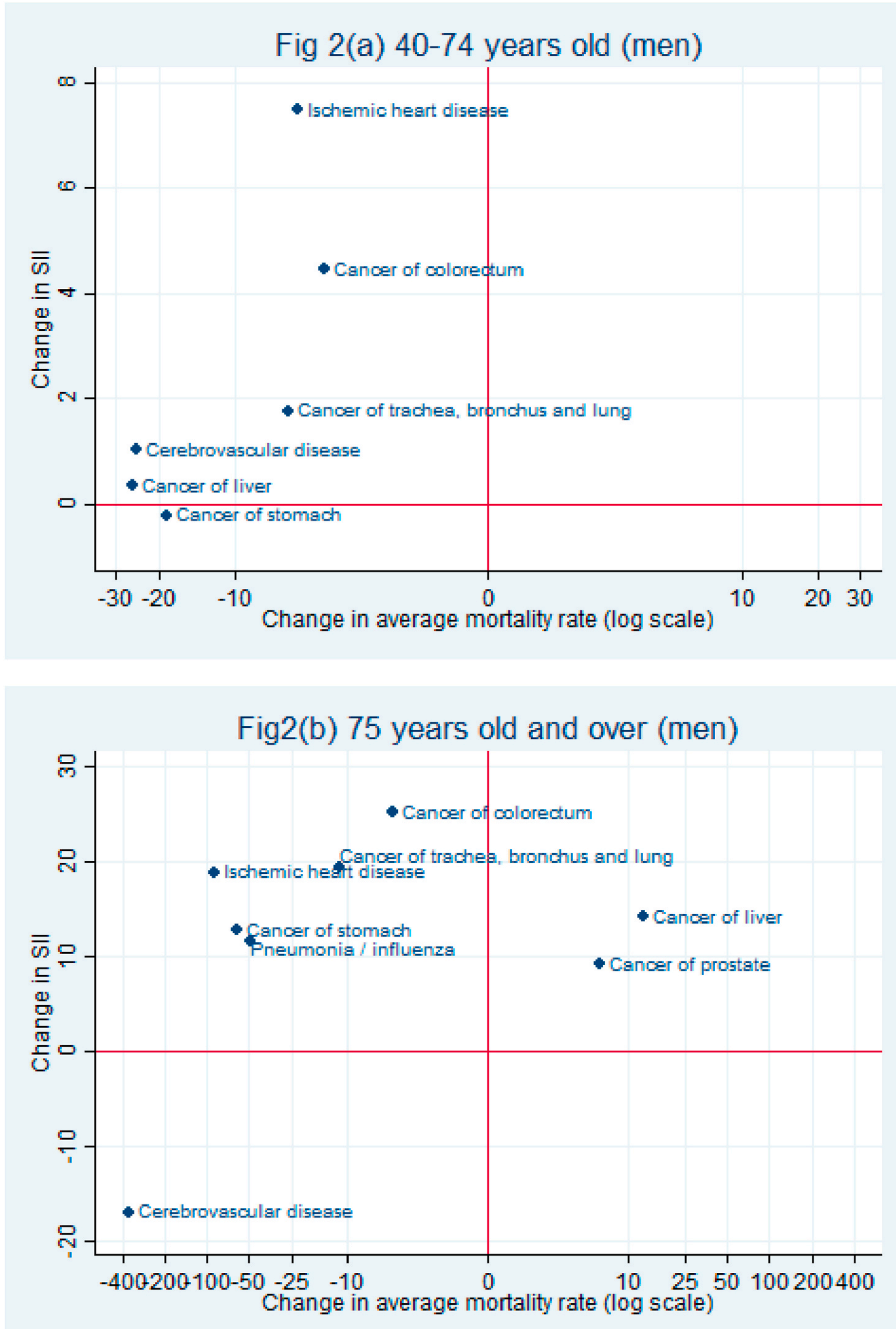
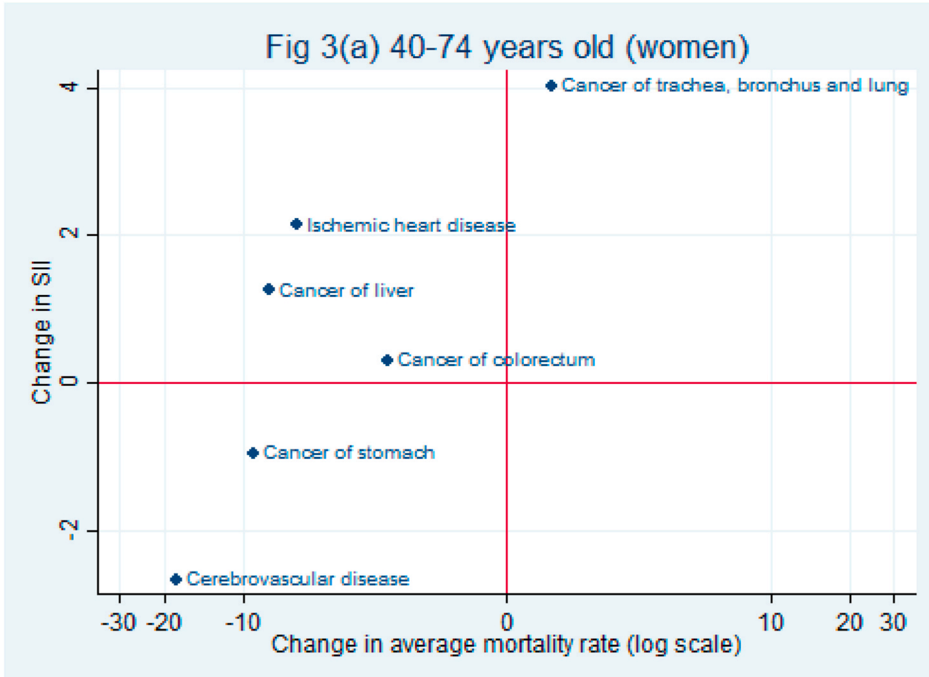



**Fig. 2.** Change from 2000 to 2010 in average mortality and slope index of inequality for internal causes of death, men aged 40–74 years (a) and men aged 75 years and over (b).

non-communicable diseases such as ischemic heart disease, cerebrovascular diseases, and some types of cancer. A closer look showed worsening conditions with increased average mortality and/or a widening gap for conditions specific to women and for external causes of death among young people. These findings require detailed discussion with consideration of the policy implications.

To address health conditions related to lifestyle behaviors, the Japanese Ministry of Health, Welfare and Labour adopted Healthy People Japan 2000, which mainly relied on a high-risk approach, conducting health screenings and individual-based behavioral modification for high-risk targets. This policy was reinforced by the introduction of the health-checkup-for-all policy in 2008, which specifically targeted obesity-related metabolic syndrome as a risk factor for diabetes and related complications (Sakamoto et al., 2018). A policy review in 2010, however, concluded that the targeted goals in population health and behavioral modification had not been achieved and called for a policy change to the population-based approach (OECD, 2019). Our results support the review's findings by showing widening inequality in mortality from conditions related to lifestyle behavior choices such as smoking, diet, and preventive service use, even under Japan's public universal health system. Because health messages and resources for behavior modification are likely to be unequally distributed across



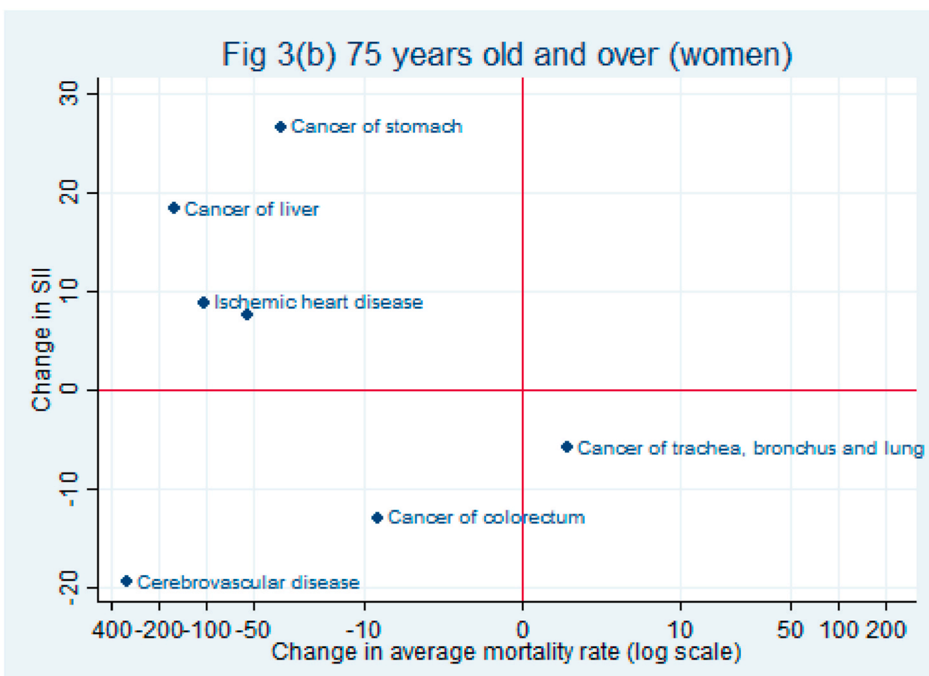




**Fig. 3.** Change from 2000 to 2010 in average mortality and slope index of inequality for internal causes of death, women aged 40–74 years (a) and women aged 75 years and over (b).

socioeconomic conditions, simply providing public prevention services may exacerbate the gap in mortality because individuals with higher socioeconomic status will have higher motivation to use these services (Ishikawa et al., 2012).

Instead, achieving equitable universal coverage requires the modification of physical and social environments to enable people to make healthier behavioral choices regardless their socioeconomic position. An example of an initiative following this approach would be banning smoking advertisements. However, the Japanese government has been reluctant to adopt an active anti-tobacco policy, despite their ratification of the World Health Organization Framework Convention on Tobacco Control (OECD, 2019; Tabuchi & Kondo, 2017). Although the prevalence of smoking has decreased among middle-aged and older men, it has remained constant among women, and there have been relative increases among young people, those with low levels of education, and those with low income (Fukuda et al., 2005; Ito et al., 2008; Tabuchi & Kondo, 2017).

In contrast to the increasing mortality gap seen for other causes of death, mortality from stomach cancer in the middle-aged subpopulations and mortality from cerebrovascular disease in the oldest subpopulations showed a narrowing gap with decreased average mortality. The recent decrease in stomach cancer in Japan has been

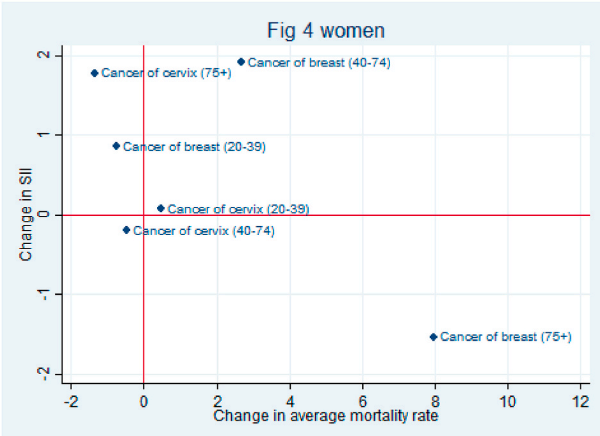



**Fig. 4.** Change from 2000 to 2010 in average mortality and slope index of inequality for death caused by breast cancer and cervical cancer among women.

attributed to the eradication of *Helicobacter pylori* infection because of general hygiene improvements (Nagao & Tsugane, 2016). The decline in stroke mortality has been attributed to better hypertension control with the Westernization of dietary habits, the availability of antihypertensive drugs under the universal insurance system, and improved housing conditions (Ikeda et al., 2011). These examples indicate that social and public health policies covering the whole population are related to successfully narrowing the mortality gap.

The theory of the fundamental causes of non-communicable diseases suggests that socioeconomic disparity in mortality from preventable diseases exists when the availability of material and non-material resources for survival depends on socioeconomic status (Phelan et al., 2004). This theory may be particularly relevant for explaining the case of breast cancer. Among women aged 20–39 or 40–75 years, as has been observed in previous studies in Europe (Mackenbach et al., 2015), we found higher mortality from breast cancer among women with higher education than among those with primary and secondary education in 2000. The education gradient was then flat in 2010, which is similar to the findings of a recent study in Europe (Gadeyne et al., 2017). Gadeyne et al. argued that the availability of information and screening programs for breast cancer were improved during the period, and highly educated women, who had higher biological risks (e.g., lower parity and delayed child bearing (Strand et al., 2007)), came to have an advantage in terms of gaining access to prevention resources, leading to an improvement in survivorship (Gadeyne et al., 2017). The Japanese government launched a cancer screening promotion program in 2006, which may have disproportionately benefited women with higher education regarding early detection.

Despite Japan's mass health checkup policy, limited opportunities have been offered for mammography screening, and its uptake rate has been as low as around 40% in Japan among women aged 50–69 years, which is one of the lowest rates in high-income Organisation for Economic Co-operation and Development (OECD) countries (OECD, 2017, OECD, 2018). As suggested in the OECD's reviews of public health issues in Japan (OECD, 2019), the country should consider free universal programs for breast and cervical cancer screening, which are available in other OECD countries.

Compared with the situation for non-communicable diseases, external causes of death appear to be more strongly influenced by social and economic policies. Japan has experienced long-term economic stagnation since the bubble economy collapse in 1991, followed by the foreign exchange shock in 1997 and the global fiscal economic shock in 2008. The decreased mortality and the narrowing of the mortality gap for accidental falls among working-age men may be related to this economic stagnation because economic downturns reduce the chance of accidents in occupations related to construction and transport, in which manual workers with low levels of education are likely to be employed (Ruhm, 2000).

During the same period, the labor market in Japan has shifted from the traditional lifetime employment system to a contract-based system in which the availability of full-time positions has strikingly decreased among young people, those nearing retirement age, and manual workers with low levels of education (Ministry of Health and Labou, 2013). These conditions may explain the "northeast" trend change in mortality from alcohol abuse among men and the increasing suicide rates among young men and women, who likely became more vulnerable to job insecurity.

Even during these economically difficult times, some positive policies appear to have worked to reduce the mortality gap. In 2002, an amendment to the Road Traffic Law was enacted after a social campaign presenting the stories of a series of children who were killed by drunk drivers. The amendment required more severe penalties for drunk driving, which resulted in a major reduction in the death toll from road accidents—from nearly 9000 deaths in 2000–5000 deaths in 2010 (Ministry of Internal Affairs and Communications, 2015). This led to improvements in both relative and absolute equality in mortality ("going southwest") for the population as a whole. Another positive example was the reduction of mortality from suicide among middle-aged men, despite the global economic crisis in 2008. Suicide casualties previously exceeded 30,000 per year after the 1997 economic shock, and the suicide rate was especially high among middle-aged working men because of economic difficulties in business (Wada et al., 2012). In 2006, the Japanese government attempted to counteract this problem with the Basic Act for Suicide Prevention, which requires employers to be responsible for mental health care and suicide prevention among their employees. Simultaneously, a community-based approach to suicide prevention targeted older adults in the community, who have a relatively high suicide risk because of social isolation and poor health (Motohashi et al., 2007). Again, however, non-regular employees and unemployed individuals were left out of these programs, which widened the gap in suicide-related mortality for young people and women, who were less likely to participate in the regular labor force.

To summarize our findings, the trends in the education-related mortality gap in Japan indicate that a high-risk approach based on behavioral choice, such as mass health checkups, has not been effective in closing the gap, whereas a universal and fundamental-cause approach seems to be more effective in reducing the education-related mortality gap. A mortality gap remains, especially for conditions related to the societal and fundamental causes of mortality, where the socioeconomically disadvantaged and other vulnerable populations such as young people and women have been left behind and neglected by the existing social/economic policy. The arguments presented in this article may generally support the policy proposal of proportionate universalism (Marmot et al., 2010).

The observation of U-shaped mortality gradients by educational attainment mainly among men in the oldest age group in 2000 may require additional discussion. This group of men were the cohort affected by the wartime experience when healthy men with low levels of education were likely to be required to serve in the military, whereas university-educated men tended to be exempted until the later period of the war. The selection effect of war survivorship may have resulted in the observation of a U-shaped association specifically among male university-graduates in the oldest age group in 2000. In 2010, men who were university graduates during the war would be aged older than 85 years, and the majority of them had died, which would diminish the U-shaped pattern.

Our study has several limitations. First, the limited availability of key variables for data linkage precluded us from implementing a one-to-one probabilistic data linkage; we instead had to use a deterministic linkage with rough segments of the link variables set using probabilistic modeling (Enamorado et al., 2019). In metropolitan areas, we had to average out a larger number of matched census observations linked with

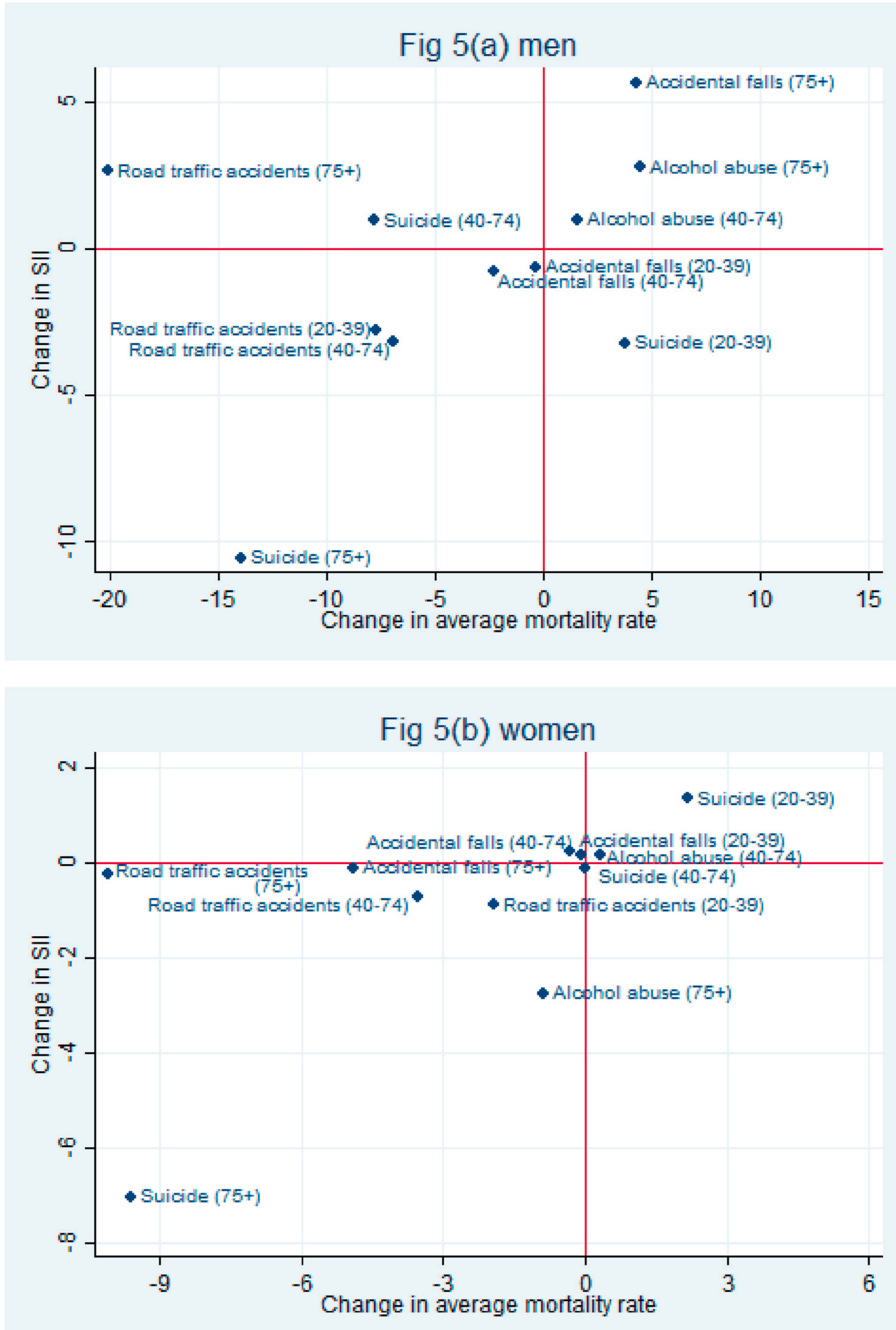



**Fig. 5.** Change from 2000 to 2010 in average mortality and slope index of inequality for external causes of death, men (a) and women (b)
In the presentation of findings for deaths from alcohol abuse, the youngest group was omitted because of the small number of deaths from alcohol abuse in this age group.

a single death record observation. Consequently, our analysis may suffer from heterogeneous error in estimated educational attainment, depending on the size of the local population. Because highly educated and young populations were likely to reside in metropolitan areas, our analysis may underestimate the effect of educational attainment in these segments of the population. Second, approximately 10% of respondents to the 2010 census had unknown educational attainment. Furthermore, through 2005, the census questionnaires were exclusively returned by mail; the 2010 survey was the first to allow the choice of mail or Internet response, which may preclude simple comparison between survey years. Third, although our study had the advantage of inferring policy impact using a nationwide repeated time series analysis in a single country to depict trend change in the education-related mortality gap, we were unable to specify the causal association with each policy. Fourth, we used prefectures as the geographical unit in estimating mortality, although there is a heterogeneous distribution of socioeconomic conditions within prefectures (Nakaya & Ito, 2019). Finally, because the census surveys collecting educational attainment information were only available once in each 10-year period, we may not have been able to detect trend changes occurring in a shorter time period. Katanoda et al. reported a decrease in breast cancer mortality after 2008 using the most recent cancer registry data available in 2015 (Katanoda et al., 2015); we did not detect this decrease in our data.

Despite these limitations, our study was the first to examine the trend change in the education-related mortality gap using a nationwide dataset over a period when a country experienced drastic changes in economic and social environments. As we observed, this mortality gap persisted despite decreased mortality on average in Japan, and the mortality gap could be reduced by adopting a universal policy addressing economic, social, and labor issues, rather than a healthcare policy. Further challenges should be overcome by extending the policy's reach to vulnerable populations to achieve universal coverage in the fight against preventable diseases.

## Ethical considerations

The need for ethical approval was waived because our study involved secondary analysis of anonymous data, under governmental official approval of data use.

## CRediT authorship contribution statement

**Megumi Kasajima:** Conceptualization, Data curation, Formal analysis, Methodology, Software, Validation, Visualization, Writing - original draft. **Hideki Hashimoto:** Conceptualization, Methodology, Funding acquisition, Supervision, Validation, Writing - review & editing.

## Declaration of competing interest

We declare that the authors have no conflicts of interest.

## Acknowledgments

We thank Dr. Koji Oba at Graduate School of Interdisciplinary Information Studies, the University of Tokyo, for his advice on statistical modeling.

Details of funding sources that supported the work.

This study is supported by Cabinet of Office, Japan (ImPACT program 2015-PM16-02 -01) http://www.jst.go.jp/impact/en/program/16.html, and the Ministry of Education, Culture, Sports, and Technology (18H04070 Grant in Aids for Scientific Research (A)) https://www.jsps.go.jp/j-grantsinaid/01_seido/01_shumoku/index.html. The use of governmental micro data was officially approved for the funded projects. The funders had no role in study design, data collection and analysis, decision to publish, or preparation of the manuscript.

## Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.ssmph.2020.100692.

## References

Abel, T., & Frohlich, K. L. (2012). Capitals and capabilities: Linking structure and agency to reduce health inequalities. *Social Science & Medicine, 74*, 236–244. https://doi.org/10.1016/j.socscimed.2011.10.028

Blakely, T., Barendregt, J. J., Foster, R. H., et al. (2013). The association of active smoking with multiple cancers: National census-cancer registry cohorts with quantitative bias analysis. *Cancer Causes & Control, 24*, 1243–1255. https://doi.org/10.1007/s10552-013-0204-2

Blakely, T., Disney, G., Atkinson, J., Teng, A., & Mackenbach, J. P. (2017). A typology for charting socioeconomic mortality gradients. *Epidemiology, 28*, 594–603. https://doi.org/10.1097/EDE.0000000000000671

Blakely, T., & Salmond, C. (2002). Probabilistic record linkage and a method to calculate the positive predictive value. *International Journal of Epidemiology, 31*, 1246–1252. https://doi.org/10.1093/ije/31.6.1246

Blakely, T., Tobias, M., & Atkinson, J. (2008). Inequalities in mortality during and after restructuring of the New Zealand economy: Repeated cohort studies. *BMJ, 336*, 371–375. https://doi.org/10.1136/bmj.39455.596181.25

Chiang, T.-l. (1999). Economic transition and changing relation between income inequality and mortality in taiwan: Regression analysis. *BMJ, 319*, 1162–1165. https://doi.org/10.1136/bmj.319.7218.1162

Enamorado, T., Fifield, B., & Imai, K. (2019). Using a probabilistic model to assist merging of large-scale administrative records. *American Political Science Review, 113*, 353–371. https://doi.org/10.1017/S0003055418000783

Fujino, Y., Tamakoshi, A., Iso, H., Inaba, Y., Kubo, T., Ide, R., Ikeda, A., Yoshimura, T., & Group, J. S. (2005). A nationwide cohort study of educational background and major causes of death among the elderly population in Japan. *Preventive Medicine, 40*, 444–451. https://doi.org/10.1016/j.ypmed.2004.07.002

Fujino, Y., Tamakoshi, A., Ohno, Y., Mizoue, T., Tokui, N., Yoshimura, T., & Group, J. S. (2002). Prospective study of educational background and stomach cancer in Japan. *Preventive Medicine, 35*, 121–127. https://doi.org/10.1006/pmed.2002.1066

Fukuda, Y., Nakamura, K., & Takano, T. (2005). Socioeconomic pattern of smoking in Japan: Income inequality and gender and age differences. *Annals of Epidemiology, 15*, 365–372. https://doi.org/10.1016/j.annepidem.2004.09.003

Gadeyne, S., Menvielle, G., Kulhanova, I., Bopp, M., Deboosere, P., Eikemo, T., Hoffmann, R., Kov Cs, K., Leinsalu, M., & Martikainen, P. (2017). The turn of the gradient? Educational differences in breast cancer mortality in 18 European populations during the 2000s. *International Journal of Cancer, 141*, 33–44. https://doi.org/10.1002/ijc.30685

Goldthorpe, J. H. (2014). The role of education in intergenerational social mobility: Problems from empirical research in sociology and some theoretical pointers from economics. *Rationality and Society, 26*, 265–289. https://doi.org/10.1177/1043463113519068

Honjo, K., Iso, H., Iwata, M., Cable, N., Inoue, M., Sawada, N., & Tsugane, S. (2012). Effectiveness of the combined approach for assessing social gradients in stroke risk among married women in Japan. *Journal of Epidemiology, 22*, 324–330. https://doi.org/10.2188/jea.JE20110147

Huisman, M., Kunst, A. E., Bopp, M., Borgan, J.-K., Borrell, C., Costa, G., Deboosere, P., Gadeyne, S., Glickman, M., & Marinacci, C. (2005). Educational inequalities in cause-specific mortality in middle-aged and older men and women in eight western European populations. *The Lancet, 365*, 493–500. https://doi.org/10.1016/S0140-6736(05)17867-2

Ikeda, N., Saito, E., Kondo, N., Inoue, M., Ikeda, S., Satoh, T., Wada, K., Stickley, A., Katanoda, K., & Mizoue, T. (2011). What has made the population of Japan healthy? *The Lancet, 378*, 1094–1105. https://doi.org/10.1016/S0140-6736(11)61055-6

Ishikawa, Y., Nishiuchi, H., Hayashi, H., & Viswanath, K. (2012). Socioeconomic status and health communication inequalities in Japan: A nationwide cross-sectional survey. *PLoS One, 7*, Article e40664. https://doi.org/10.1371/journal.pone.0040664

Ito, S., Takachi, R., Inoue, M., Kurahashi, N., Iwasaki, M., Sasazuki, S., Iso, H., Tsubono, Y., Tsugane, S., & Group, J. S. (2008). Education in relation to incidence of and mortality from cancer and cardiovascular disease in Japan. *The European Journal of Public Health, 18*, 466–472. https://doi.org/10.1093/eurpub/ckn052

Kagamimori, S., Gaina, A., & Nasermoaddeli, A. (2009). Socioeconomic status and health in the Japanese population. *Social Science & Medicine, 68*, 2152–2160. https://doi.org/10.1016/j.socscimed.2009.03.030

Katanoda, K., Hori, M., Matsuda, T., Shibata, A., Nishino, Y., Hattori, M., Soda, M., Ioka, A., Sobue, T., & Nishimoto, H. (2015). An updated report on the trends in cancer incidence and mortality in Japan, 1958–2013. *Japanese Journal of Clinical Oncology, 45*, 390–401. https://doi.org/10.1093/jjco/hyv002

Kimura, T., Iso, H., Honjo, K., Ikehara, S., Sawada, N., Iwasaki, M., & Tsugane, S. (2016). Educational levels and risk of suicide in Japan: The Japan public health center study (JPHC) cohort I. *Journal of Epidemiology, 26*, 315–321. https://doi.org/10.2188/jea.JE20140253

Kjellsson, G., Gerdtham, U.-G., & Petrie, D. (2015). Lies, damned lies, and health inequality measurements: Understanding the value judgments. *Epidemiology, 26*, 673. https://doi.org/10.1097/EDE.0000000000000319

Kohler, I. V., Martikainen, P., Smith, K. P., & Elo, I. T. (2008). Educational differences in all-cause mortality by marital status—evidence from Bulgaria, Finland and the United States. *Demographic Research, 19*, 2011–2042. https://doi.org/10.4054/DemRes.2008.19.60

Koike, S., & Yamauchi, M. (2014). Demographic analysis of the occurrence of unknown response in 2010 census survey [in Japanese]. *Journal of Population Problems, 70*, 325–338.

Krueger, P. M., Tran, M. K., Hummer, R. A., & Chang, V. W. (2015). Mortality attributable to low levels of education in the United States. *PLoS One, 10*, Article e0131809. https://doi.org/10.1371/journal.pone.0131809

Mackenbach, J. P. (2012). The persistence of health inequalities in modern welfare states: The explanation of a paradox. *Social Science & Medicine, 75*, 761–769. https://doi.org/10.1016/j.socscimed.2012.02.031

Mackenbach, J. P. (2015). Should we aim to reduce relative or absolute inequalities in mortality? *The European Journal of Public Health, 25*, 185. https://doi.org/10.1093/eurpub/cku217

Mackenbach, J. P., Hu, Y., Artnik, B., Bopp, M., Costa, G., Kalediene, R., Martikainen, P., Menvielle, G., Strand, B. H., & Wojtyniak, B. (2017). Trends in inequalities in mortality amenable to health care in 17 European countries. *Health Affairs, 36*, 1110–1118. https://doi.org/10.1377/hlthaff.2016.1674

Mackenbach, J. P., Kulhánová, I., Bopp, M., Deboosere, P., Eikemo, T. A., Hoffmann, R., Kulik, M. C., Leinsalu, M., Martikainen, P., & Menvielle, G. (2015). Variations in the relation between education and cause-specific mortality in 19 European populations: A test of the "fundamental causes" theory of social inequalities in health. *Social Science & Medicine, 127*, 51–62. https://doi.org/10.1016/j.socscimed.2014.05.021

Mackenbach, J. P., Kunst, A. E., Cavelaars, A. E., Groenhof, F., Geurts, J. J., & Health EWGoSIi. (1997). Socioeconomic inequalities in morbidity and mortality in western

Europe. *The Lancet, 349*, 1655–1659. https://doi.org/10.1016/s0140-6736(96)07226-1
Mackenbach, J. P., Stirbu, I., Roskam, A.-J. R., Schaap, M. M., Menvielle, G., Leinsalu, M., & Kunst, A. E. (2008). Socioeconomic inequalities in health in 22 European countries. *New England Journal of Medicine, 358*, 2468–2481. https://doi.org/10.1056/NEJMsa0707519
Marmot, M. (2005). Social determinants of health inequalities. *The Lancet, 365*, 1099–1104. https://doi.org/10.1016/S0140-6736(05)71146-6
Marmot, M., Allen, J., Goldblatt, P., Boyce, T., Mcneish, D., Grady, M., & Geddes, I. (2010). *The Marmot review: Fair society, healthy lives*. London: UCL.
Ministry of Education. (1981). Japan's modern educational system: A history of the first hundred years. https://www.mext.go.jp/b_menu/hakusho/html/others/detail/1317220.htm accessed 10 September 2020.
Ministry of Health, Labour and Welfare. (2013). *White paper on the Labour economy 2013*. Tokyo: Ministry of Health, Labour and Welfare.
Ministry of Internal Affairs and Communications. (2015). *Statistical handbook of Japan 2015*. Tokyo: Statistics Bureau.
Ministry of Justice. (2017). Statistics of foreign population in Japan (1979–2016) [in Japanese] http://www.moj.go.jp/content/001237697.pdf accessed 19 March 2020.
Montez, J. K., Hummer, R. A., Hayward, M. D., Woo, H., & Rogers, R. G. (2011). Trends in the educational gradient of US adult mortality from 1986 through 2006 by race, gender, and age group. *Research on Aging, 33*, 145–171. https://doi.org/10.1177/0164027510392388
Moreno-Betancur, M., Latouche, A., Menvielle, G., Kunst, A. E., & Rey, G. (2015). Relative index of inequality and slope index of inequality: A structured regression framework for estimation. *Epidemiology, 26*, 518–527. https://doi.org/10.1097/EDE.0000000000000311
Motohashi, Y., Kaneko, Y., Sasaki, H., & Yamaji, M. (2007). A decrease in suicide rates in Japanese rural towns after community-based intervention by the health promotion approach. *Suicide and Life-Threatening Behavior, 37*, 593–599. https://doi.org/10.1521/suli.2007.37.5.593
Nagao, M., & Tsugane, S. (2016). Cancer in Japan: Prevalence, prevention and the role of heterocyclic amines in human carcinogenesis. *Genes and Environment, 38*, 16. https://doi.org/10.1186/s41021-016-0043-y
Nakaya, T., & Ito, Y. (2019). *The atlas of health inequalities in Japan*. Cham: Springer Nature. https://doi.org/10.1007/978-3-030-22707-4
OECD. (2017). Quality and outcomes of care: Screening, survival and mortality for breast cancer. In *OECD, health at a glance 2017: OECD indicators* (pp. 122–123). Paris: OECD Publishing. https://doi.org/10.1787/health_glance-2017-en.
OECD. (2018). OECD health statistics accessed 20 December 2019 https://stats.oecd.org/index.aspx?queryid=30159.
OECD. (2019). OECD reviews of public health: Japan. In *OECD, A healthier tomorrow* (pp. 26–31). Paris: OECD Publishing. https://doi.org/10.1787/9789264311602-en.
Phelan, J. C., Link, B. G., Diez-Roux, A., Kawachi, I., & Levin, B. (2004). "Fundamental causes" of social inequalities in mortality: A test of the theory. *Journal of Health and Social Behavior, 45*, 265–285. https://doi.org/10.1177/002214650404500303
Rogers, R. G., Everett, B. G., Zajacova, A., & Hummer, R. A. (2010). Educational degrees and adult mortality risk in the United States. *Biodemography and Social Biology, 56*, 80–99. https://doi.org/10.1080/19485561003727372
Ross, C. E., Masters, R. K., & Hummer, R. A. (2012). Education and the gender gaps in health and mortality. *Demography, 49*, 1157–1183. https://doi.org/10.1007/s13524-012-0130-z
Ruhm, C. J. (2000). Are recessions good for your health? *Quarterly Journal of Economics, 115*, 617–650. https://doi.org/10.1162/003355300554872
Sakamoto, H., Rahman, M., Nomura, S., Okamoto, E., Koike, S., Yasunaga, H., & Ghaznavi, C. (2018). *Japan health system review*. New Delhi: World Health Organization Regional Office for South-East Asia.
Strand, B. H., Kunst, A., Huisman, M., Menvielle, G., Glickman, M., Bopp, M., Borell, C., Borgan, J. K., Costa, G., & Deboosere, P. (2007). The reversed social gradient: Higher breast cancer mortality in the higher educated compared to lower educated. A comparison of 11 European populations during the 1990s. *European Journal of Cancer, 43*, 1200–1207. https://doi.org/10.1016/j.ejca.2007.01.021
Tabuchi, T., & Kondo, N. (2017). Educational inequalities in smoking among Japanese adults aged 25–94 years: Nationally representative sex- and age-specific statistics. *Journal of Epidemiology, 27*, 186–192. https://doi.org/10.1016/j.je.2016.05.007
Teng, A., Atkinson, J., Disney, G., Wilson, N., & Blakely, T. (2017). Changing smoking-mortality association over time and across social groups: National census-mortality cohort studies from 1981 to 2011. *Scientific Reports, 7*, 1–10. https://doi.org/10.1038/s41598-017-11785-x
Wada, K., Kondo, N., Gilmour, S., Ichida, Y., Fujino, Y., Satoh, T., & Shibuya, K. (2012). Trends in cause specific mortality across occupations in Japanese men of working age during period of economic stagnation, 1980-2005: Retrospective cohort study. *BMJ, 344*, Article e1191. https://doi.org/10.1136/bmj.e1191