Sociodemographic patterns of COVID-19 mortality: the 2020 Japanese census-linked mortality database

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Summary

Background Owing to the lack of sociodemographic mortality statistics in Japan, linking existing individual statistical data could be cost-effective and, therefore, highly sustainable for monitoring health inequalities regarding urgent health issues. We investigated nationwide coronavirus disease 2019 (COVID-19) cause-specific mortality by sociodemographic characteristics compared with all-cause mortality in Japan, using our unique linkage method among non-institutionalised citizens.

Methods Using the 2020 Japanese census-linked mortality database, we calculated age-standardised mortality rates from all-cause and COVID-19 by region, marital status, household size ('living alone' to 'five or more'), educational level, area deprivation index (ADI: municipality-level population quantiles), and occupational class. We then applied multivariable modified Poisson regression analysis to investigate the relationship between all-cause and COVID-19 mortality with sociodemographic characteristics, excluding occupational class. All analyses were performed by sex and period (i.e., during Delta variant dominance in 2021 and Omicron variant dominance in 2022). ADI analyses also accounted for metropolitan residency (the Tokyo and Osaka metropolitan areas vs. non-metropolitan areas).

Findings This analysis included 80,135,688 non-institutionalised Japanese individuals (aged 30–89 years) linked to 1,895,080 all-cause deaths between October 2020 and December 2022, including 34,213 COVID-19-related deaths. After controlling for sociodemographic characteristics, marital status (e.g., for single men, mortality rate ratio: 2.02 (95% confidence intervals [CI]: 1.90–2.14), compared with married men), and low education level (e.g., low-educated women: 1.49 [95% CI: 1.38–1.61], compared with high-educated women) were associated with increased COVID-19 mortality, similar to the trends in all-cause deaths. Additionally, having a large household was associated with increased COVID-19 mortality rate ratio (e.g., women living with five or more people: 1.69 [95% CI: 1.54–1.84], compared with women living alone; p for trend < 0.0001: using ordinal variables of household size). These patterns were consistent across sexes and variant periods. COVID-19 mortality was not significantly associated with ADI (mortality rate ratio for men in the most deprived municipalities compared with in the least deprived municipalities: 0.95 [95% CI: 0.89–1.01], p for trend = 0.069; women: 0.97 [95% CI: 0.90–1.06], p for trend = 0.285), contrasting with all-cause mortality rate ratios, which increased with deprivation. ADI-related trends varied by variant period and metropolitan status.

Interpretation In Japan, sociodemographic patterns of COVID-19 mortality for the non-institutionalised population related to marital status and education reflect underlying health inequalities—all-cause mortality patterns. However, the lack of an association with area deprivation marks a divergence from typical all-cause mortality patterns. Notably, residing in large households was uniquely associated with increased COVID-19 mortality, an uncommon feature among cause-specific mortality patterns.

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Translation: For the Japanese translation of the abstract see Supplementary Materials section.

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Research in context

Evidence before this study

A scoping review published in *The Lancet Public Health* revealed that coronavirus disease 2019 (COVID-19) mortality rates were higher in areas of socioeconomic disadvantage than in affluent areas. This review covered 95 research papers from five World Health Organization (WHO) regions as of 31 December 2021, including a cross-sectional study conducted in Japan. We also searched PubMed from inception to 1 December 2024 for original research explaining socioeconomic inequalities in COVID-19 mortality using search terms (‘socioeconomic’ AND ‘mortality’ AND ‘COVID-19’). The reference lists of the included studies were screened to identify additional relevant studies. Existing literature indicates that inequalities in society are based on socioeconomic factors such as sex, race, ethnicity, income, area poverty level, education, and occupation. In addition, several studies revealed an association between household composition and severe COVID-19 outcomes. Although there is a growing body of evidence, most studies are cross-sectional, except in countries with advanced health data linkage systems, such as Denmark and England. There is little research involving the use of large-scale census-linked mortality data, which would enable the investigation of COVID-19 cause-specific mortality according to sociodemographic characteristics by adjusting for each variable. The use of large-scale census-linked individual mortality data enabled us to better monitor health inequalities for urgent health issues. Such high-quality statistics on mortality inequalities would facilitate more sophisticated policies and interventions to reduce health inequalities.

Added value of this study

One key added value of this study is that socioeconomic inequalities in COVID-19 cause-specific mortality reflect preexisting health inequalities in society. This study showed that marital status (single or divorced) and low education were associated with increased COVID-19 mortality rates; however, area deprivation was not associated with COVID-19 mortality at the national level in Japan and should be interpreted with caution. These findings were divergent from findings in other countries. Moreover, living with more household members showed a significant increase in COVID-19 mortality rate, after controlling for other sociodemographic characteristics. The rate of all-cause mortality, including COVID-19 cause-specific mortality, is generally high among single and divorced individuals; however, the health sector and large-household families should be aware of the potentially high mortality rate of emerging infectious diseases among large households. Additionally, the census-linked mortality database used in this study offered several key analytical advantages. First, it consisted of data for approximately 109 million Japanese citizens, with approximately 2.4 million deaths, thus covering the largest Japanese cohort. Second, the census-linked mortality database provided a prospective individual-based analysis starting from the 2020 census, eliminating the effect of numerator–denominator bias. Moreover, linking existing digitised individual statistical data is cost-effective and, therefore, highly sustainable. The large-scale census-linked mortality database provided updated insights into sociodemographic mortality patterns, which is essential for a comprehensive evaluation of public health practice and future planning of interventions.

Implications of all the available evidence

Evidence from East Asian countries emphasises that careful monitoring using census-linked mortality or health databases is necessary to better understand health inequalities, even in countries with the world’s longest life expectancy. Vulnerable groups do not exist immediately global health crises occur, and existing vulnerable groups are certainly a pre-prevalent in the next health crises, such as emerging infectious diseases. In addition, densely populated and highly urbanised cities, such as Tokyo and Osaka, are at high risk of emerging infectious diseases. In particular, the living conditions for large families in metropolitan areas (e.g., crowded housing and decreasing floor space due to rising rents) are considered health risk factors in densely populated cities worldwide, in addition to deprived areas.

Introduction

The coronavirus disease (COVID-19) pandemic created public health challenges in densely populated and highly urbanised countries. Japan did not experience as many COVID-19 cases in 2020 as other countries[1]; however, Japan experienced approximately 2% and 6% all-cause age-standardised mortality (ASMR) increases in 2021 and 2022, respectively, with excess deaths, which was mainly attributed to increase in COVID-19 cause-specific mortality.[2,3] In Japan, the COVID-19 vaccine became available in February 2021, and its use was started only for medical workers but gradually expanded to the elderly and others. However, a total of approximately 34 million confirmed cases of COVID-19 were reported up to May 7, 2023, when the Japanese government ended surveillance of all cases, and the death toll was 74,688 by that date.[1]

The direct impact of the COVID-19 pandemic on mortality was reported to be significantly associated with sociodemographic factors worldwide.[4,5] The COVID-19 pandemic has widened health inequalities in society based on sociodemographic factors[6] such as sex, race, ethnicity, income, area poverty level, education, and occupation.[7–14] In addition, several studies revealed an association between household composition and severe COVID-19-related outcomes, implying that living with more family members was associated with increased COVID-19-related mortality.[15–18] A cross-sectional study of the 47 prefectures in Japan suggested that a pattern of socioeconomic inequalities in COVID-19 (through February 2021) was similar to those observed in the US and European countries.[19] However, insights into COVID-19 cause-specific mortality by individual sociodemographic characteristics in the Japanese population remain scarce owing to the lack of a national health inequality monitoring framework such as a health database linkage system (e.g., Denmark and England).[7,14–17] This obstructs understanding of the sources of vulnerability to COVID-19, which is essential for a comprehensive evaluation of Japan's countermeasures and future planning of interventions. Linking existing digitised individual statistical data is cost-effective and, therefore, highly sustainable under digital transformation.

Although the Japanese government has issued a state of emergency several times since April 2020, the target regions were mainly populous prefectures such as Tokyo and Osaka.[1] This is because Tokyo and Osaka Prefectures (i.e., metropolitan areas) have been the epicentres of the COVID-19 pandemic, and preventing the spread of infection from those areas to other local regions was challenging. In Japan, COVID-19 incidence remained low until the end of 2021 (during the Alpha and Delta variant dominance periods), especially in non-metropolitan areas, but increased from 2022 (after the Omicron variant dominance period) in non-metropolitan areas.[20] Indeed, Iwate Prefecture (Tohoku region: the northeast area of Japan's main island) was the last to report a COVID-19 case in July 2020. Although COVID-19 cause-specific mortality was higher in more deprived places and communities worldwide,[4] sociodemographic patterns of COVID-19 cause-specific mortality in Japan may be different because Tokyo and Osaka Prefectures and surrounding areas (areas with high COVID-19 prevalence) generally include less deprived regions than non-metropolitan areas (e.g., Iwate Prefecture), when considered at the national level.

Japan's lessons are useful for tackling global health issues such as the COVID-19 crisis because the island nation has unique features; for example, high standards for general hygiene, an affordable medical care system, and high levels of social cohesion, which may cause high peer pressure to adhere to COVID-19 preventive measures. We aimed to investigate COVID-19 cause-specific mortality according to sociodemographic characteristics, compared with all-cause mortality in the Japanese non-institutionalised population using census records of 100 million individuals linked with mortality data to analyse the direct consequences of the COVID-19 pandemic in Japan.

Methods

Data source

This analysis involved a secondary use of data from the Population Census (hereinafter, 'the census') and the National Vital Statistics (hereinafter, 'the vital statistics') data anonymised by the Ministry of Internal Affairs and Communications (MIC) and the Ministry of Health, Labour and Welfare (MHLW).[21,22] The census and vital statistics were complete surveys for over 120 million persons living in Japan every 5 years and approximately 1.5 million deaths per year, respectively.[21,22] The MIC and MHLW provided the data after ensuring data management and protection compliance, according to Article 33 of Japan's Statistics Act. We developed the 2020 Japanese census-linked mortality database (hereinafter, 'the census-linked mortality database') covering data of 100 million Japanese individuals and millions of death records, based on our previous work.[23,24] The original concept used for data linkage has been presented in previous reports in which the 2010 census data was used.[23,24] Fig. 1 shows an overview of the census-linked mortality database. The census-linked mortality database is based on anonymised microdata from the 2020 census including 117,827,253 non-institutionalised Japanese persons [57,475,369 men and 60,351,884 women], conducted on 1 October 2020 by the MIC.[22] We also obtained all death records (n = 3,370,600 [1,722,346 men and 1,648,254 women]) including COVID-19 death records (n = 66,314 [35,976 men and 30,338 women]) between October 2020 and December 2022, from the vital statistics collected annually by the MHLW.[21] The MHLW follows an algorithm for classifying the cause of death based on the International Classification of Diseases, 10th Revision (ICD-10).[21] COVID-19 cause-specific deaths were coded as "U07" (hereafter, "COVID-19 death" or "COVID-19 mortality"). These data include all regions (47 prefectures) of Japan. Foreigners living in Japan were excluded from analysis. We also excluded individuals living in school dormitories, Self-Defence Force bases, and hospitals (i.e., patients hospitalised for more than three months) owing to census–death record linkage difficulties.

The database includes the number of deaths stratified by (1) marital status, (2) household size, (3) educational level, (4) occupational class (aged 30–69 years only), (5) region (prefecture [n = 47], secondary medical area [n = 334], and municipality [n = 1718]), and

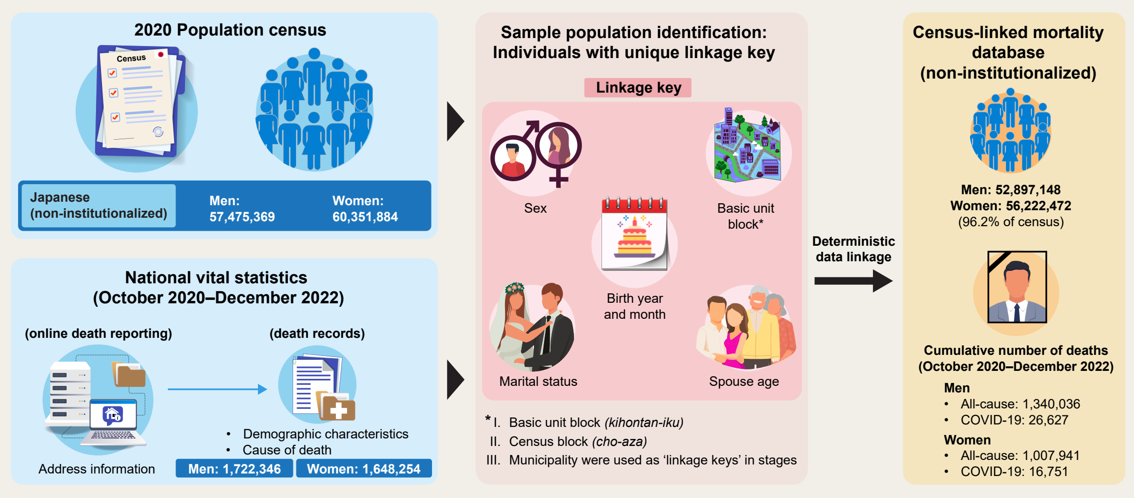

Fig. 1: The 2020 Japanese census-linked mortality database across all age groups (October 2020 and December 2022).

(6) census-derived indicator (e.g., neighbourhood socioeconomic conditions).[22] Secondary medical areas are legally defined (the Medical Services Act) and are mainly concerned with most admissions, and surgical, emergency, and ambulatory services. Usually, a prefecture is divided into five to ten secondary medical areas based on its medical resources, transportation, and geographical situation. We used the area deprivation index (ADI) developed by one of the authors, consisting of weighted sums of some census-based variables, based on the 2020 census data,[25–27] as follows:

$$
\begin{aligned}
\mathrm{ADI_i} = \mathrm{k} \times \big(&2.99 \times \textit{proportion of older couple households}_i + 7.57 \times \textit{proportion of older single households}_i \\
&+ 17.4 \times \textit{proportion of single mother households}_i + 2.22 \times \textit{proportion of rental houses}_i + 4.03 \\
&\times \textit{proportion of sales and service workers}_i + 6.05 \times \textit{proportion of agricultural workers}_i + 5.38 \\
&\times \textit{proportion of blue-collar workers}_i + 18.3 \times \textit{unemployment rate}_i\big)
\end{aligned}
$$

where *i* is a municipality index; *k* is a positive constant and can be any positive number used to determine the percentile rank of a municipality. For this study, the ADI was converted into variables consisting of population quantile categories based on municipality level, ranging from Q1 (least deprived) to Q5 (most deprived). Hence, Q1 (least deprived) includes 153 large populous municipalities, while Q5 (most deprived) includes 861 small populous municipalities.

Data linkage

Five variables were used as 'linkage keys' owing to the lack of an official personal identification code in Japan. These consisted of sex, birth year/month, address (basic unit block: about 1.9 million census units), marital status, and age of spouse.[23] Address information from the census was defined as the place where individuals lived, whereas address information from the vital statistics referred to the place of administrative registration at death. Address information from the census was used as the baseline for mortality analyses. Although the vital statistics also included the place of death (e.g., "hospital" or "home"), this information was not used for the present analysis.

A total of 109,119,620 non-institutionalised individuals with unique linkage keys (92.6% of all non-institutionalised individuals) were identified from the census and included in the database, whereas 8,707,633 individuals (7.4% of all non-institutionalised individuals) were excluded owing to duplicate linkage keys, missing marital status data, or unidentifiable addresses. For this analysis, (I) basic unit block, (II) census block (*cho-aza*), and (III) municipality were used as linkage keys for address in stages. Death records were linked to the census data of the cohort using a multistage deterministic linkage method based on linkage level. The highest linkage level indicates complete matching 'sex', 'birth year/month', 'address (basic unit block)', 'marital status (married)', and 'age of spouse', whereas the lowest linkage level indicates complete matching 'sex', 'birth year/month', 'address (municipality)', and 'marital status'. The final census-linked mortality database included 109,119,620 non-institutionalised Japanese citizens (52,897,148 men and 56,222,472 women: 92.6% of all non-institutionalised individuals), with 2,347,977 death records (1,340,036 men and 1,007,941 women: 69.7% of all recorded deaths), between October 2020 and December 2022. Of these, 43,378 (26,627 men and 16,751 women) COVID-19 death records (65.4% of all COVID-19 deaths) were included in the database. Primary analyses were conducted on the non-institutionalised Japanese population from the census as of 1 October 2020.

Analysis

Validity confirmation of the census-linked mortality database

First, nationwide trends in daily COVID-19 incidence and deaths (total reported deaths and census-linked death records), and age distributions of death were confirmed using the national report (Supplementary Figure S1). Second, comparison of all-cause and COVID-19 ASMRs by age (restricted to 30–89 years) was assessed using the vital statistics (complete registry) and census-linked mortality database (Supplementary Table S1). We applied the direct standardisation method based on the 2015 Japan Standard Population report.[28] Because age-restricted analyses provide more accurate estimations of census-linked mortality, we restricted analyses to men and women aged 30–89 years. Third, crude COVID-19 mortality rate and mortality rate ratios were calculated by age using Poisson regression analysis, with robust estimation of standard error, to confirm COVID-19 mortality (Supplementary Table S2). Fourth, the correlations between COVID-19 ASMR (aged 30–89 years), vital statistics (complete registry), and census-linked mortality in 47 prefectures were assessed to examine the validity of census-linked mortality (Supplementary Figure S2).

Main analysis

COVID-19 ASMR ratios were calculated based on the national average for both sexes, by secondary medical area, to confirm the geographic distribution of COVID-19 mortality rate in Japan. In addition, changes in COVID-19 ASMRs by municipality between 2021 and 2022 were calculated and visualised, focussing on Osaka and Tokyo and surrounding areas with the highest COVID-19 ASMRs in Japan (Supplementary Figure S3). The correlation between population density and COVID-19 mortality was also evaluated by municipality level, focussing on Osaka and Tokyo (Supplementary Figure S4).

All-cause and COVID-19 ASMRs were calculated by marital status (single, married, widowed, or divorced), household size (‘living alone’ to ‘five or more’), educational level (high (International Standard Classification of Education [ISCED]: 5–8), middle (ISCED: 3, 4), low (ISCED: 1, 2), or unknown),[23] ADI (‘Quintile 1 [least deprived]’–‘Quintile 5 [most deprived]’),[25–27] and occupational class (aged 30–69 years: five categories defined by the Erikson–Goldthorpe–Portocarero scheme and ‘non-employee/unknown’).[24] Multivariable Poisson regression analysis with robust estimation of standard error was performed to account for overdispersion, with individual age (5-year group), marital status, household size, educational level, ADI (municipality-level population quantiles), and prefecture (n = 47) as covariates (Model 1) to calculate mortality rate ratios. Person-years at risk were included as the offset, and all-cause and COVID-19 death counts were used as outcomes, respectively. Trend analyses were also performed using ordinal variables: household size (living alone: 1–5 or more: 5), educational level (high: 1, middle: 2, low: 3, unknown: omitted), and ADI (quintiles 1–5). Occupational class was excluded from the covariates because it is age-restricted; COVID-19 mortality was very low among the working-age population (69 years and under) compared with the non-working-age population (70 years and over) in Japan.

Analysis was stratified by sex because age-adjusted Poisson regression with interaction terms between sex and each sociodemographic characteristic indicated significant interactions for marital status, household size, and educational level. Analyses were also stratified by COVID-19 variant dominance period (i.e., the entire period and subdivisions into Delta variant dominance in 2021 and Omicron variant dominance in 2022). To investigate the heterogeneity of the association between ADI and COVID-19 mortality in metropolitan areas, Model 2 extended Model 1 by adding an interaction term between ADI (treated as an ordinal variable: quintiles 1–5) and residence in endemic metropolitan areas (the Tokyo and Osaka metropolitan areas vs. non-metropolitan areas). The Tokyo metropolitan area includes Saitama, Chiba, Tokyo, and Kanagawa Prefectures. In contrast, the Osaka metropolitan area includes Kyoto, Osaka, Hyogo, and Nara Prefectures, where COVID-19 incidence was consistently high throughout the pandemic in Japan.[20]

STATA version 17/ME (Stata Corp, College Station, TX, USA) was used for analyses and data management, and a p value of <0.05 was considered significant.

Sensitivity analysis

We excluded non-institutionalised Japanese aged 90 years and over (n = 1,474,138, including 9081 COVID-19 deaths) and institutionalised Japanese of all ages (n = 1,603,329, including 5366 COVID-19 deaths) from the primary analysis due to (1) the low accuracy of census–death record linkage for the oldest old populations and (2) the focus on analysis of the general community-dwelling population. However, because these populations experienced high COVID-19 mortality rates worldwide and are of particular interest for analysis, they were included in a sensitivity analysis. Multivariable Poisson regression analysis (Model 1) was conducted by sex among non-institutionalised and institutionalised individuals aged 30 years and over, including residents of geriatric health service facilities.

Role of the funding source

The funders of the study had no role in study design, data collection, data analysis, data interpretation, or the decision to submit the manuscript for publication.

Ethics approval

After considering the need for ethical approval by the authors, ethical approval was not obtained for this study, as it involved a secondary use of census and vital statistical data, which were anonymised by the MIC and the MHLW. The MIC and the MHLW provided data after ensuring data management and protection compliance.

Results

This study included 80,135,688 non-institutionalised Japanese individuals (aged 30–89 years) linked to 1,895,080 all-cause deaths, including 34,213 COVID-19 deaths. Fig. 2 shows the geographic distribution of

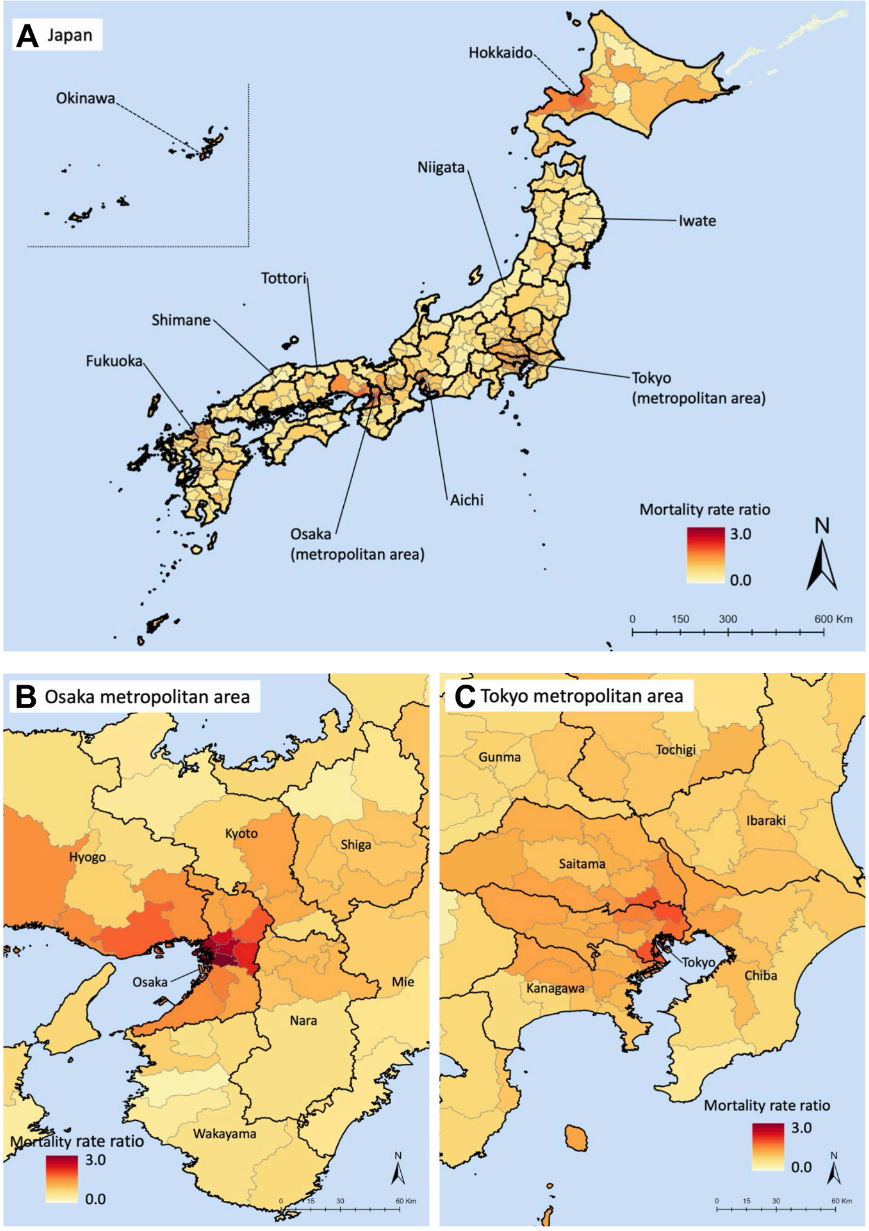

Fig. 2: Geographic distributions of COVID-19 mortality rate ratios in Japan by secondary medical areas (age-standardised mortality rate ratios referenced to the national average aged 30–89 years for both sexes): from October 2020 to December 2022.

COVID-19 mortality rate ratios in Japan by secondary medical area. The Osaka metropolitan area (approximately 2.8 times the risk, compared with the national average) and the Tokyo metropolitan area (approximately 1.5 times the risk) had the highest mortality rates. Conversely, Tohoku region (the northeast area of Japan's main island), where all-cause mortality is generally high, had low COVID-19 mortality.

Tables 1 and 2 show the population, number of deaths, and COVID-19 ASMRs according to the sociodemographic characteristics of men and women, respectively. COVID-19 ASMRs for men and women were 28.6 and 11.0 per 100,000 person-years, respectively. Marital status was significantly associated with COVID-19 mortality for both sexes: for example, the multivariable-adjusted mortality rate ratios for single and divorced men were 2.02 (95% confidence intervals [CI]: 1.90–2.14) and 1.99 (95% CI: 1.86–2.13), respectively, compared with married men. These trends were comparable to those of all-cause mortality for both sexes. Household size was significantly associated with COVID-19 mortality for both sexes: for example, the multivariable-adjusted mortality rate ratios for men and women living with five or more people were 1.51 (95% CI: 1.41–1.63) and 1.69 (95% CI: 1.54–1.84), respectively, compared with those living alone, after controlling for other sociodemographic characteristics (p for trend < 0.0001 for both sexes). These trends were divergent from those of all-cause mortality for both sexes: for example, the multivariable-adjusted all-cause

	Population		COVID-19					All-cause	
			Number of deaths	ASMR[a]	ASMR ratio	Multivariable adjusted[b]		Multivariable adjusted[b]	
	n	(%)				Mortality rate ratio	95% CI	Mortality rate ratio	95% CI
Total	38,544,154		22,612	28.6					
Marital status									
Single	7,637,696	(19.8)	1846	43.1	1.63	2.02	(1.90–2.14)	1.92	(1.89–1.94)
Married	27,792,457	(72.1)	16,743	26.4	Reference	Reference		Reference	
Widow	1,220,541	(3.2)	2808	34.4	1.30	1.36	(1.29–1.43)	1.24	(1.22–1.26)
Divorced	1,893,460	(4.9)	1215	43.2	1.64	1.99	(1.86–2.13)	1.84	(1.81–1.87)
Household size									
Living alone	5,419,234	(14.1)	3464	33.3	Reference	Reference	*(p for trend ≤ 0.0001)*	Reference	*(p for trend < 0.0001)*
Two	12,797,139	(33.2)	10,760	26.8	0.80	1.22	(1.16–1.29)	1.14	(1.12–1.16)
Three	9,554,829	(24.8)	4885	30.3	0.91	1.43	(1.35–1.52)	1.19	(1.17–1.22)
Four	6,974,804	(18.1)	1975	30.8	0.92	1.51	(1.41–1.62)	1.17	(1.15–1.19)
Five or more	3,798,148	(9.9)	1528	27.5	0.83	1.51	(1.41–1.63)	1.16	(1.14–1.19)
Educational level									
High (ISCED: 5–8)	15,016,727	(39.0)	4582	24.9	Reference	Reference	*(p for trend < 0.0001)*	Reference	*(p for trend < 0.0001)*
Middle (ISCED: 3, 4)	14,735,914	(38.2)	8101	27.0	1.08	1.21	(1.16–1.27)	1.20	(1.18–1.23)
Low (ISCED: 1, 2)	4,560,550	(11.8)	6276	30.5	1.22	1.33	(1.27–1.40)	1.33	(1.30–1.36)
Unknown	4,230,963	(11.0)	3653	41.4	1.66	1.62	(1.54–1.72)	1.47	(1.42–1.51)
Areal deprivation index (municipality level)									
Quintiles 1 (least deprived)	7,125,388	(18.5)	4329	34.6	Reference	Reference	*(p for trend = 0.069)*	Reference	*(p for trend < 0.0001)*
Quintiles 2	7,716,151	(20.0)	4334	28.3	0.82	0.97	(0.92–1.03)	1.02	(0.98–1.05)
Quintiles 3	7,802,995	(20.2)	4234	26.8	0.77	0.95	(0.89–1.005)	1.04	(1.004–1.07)
Quintiles 4	7,865,480	(20.4)	4427	26.5	0.77	0.94	(0.89–0.999)	1.05	(1.02–1.09)
Quintiles 5 (most deprived)	8,034,140	(20.8)	5288	28.1	0.81	0.95	(0.89–1.01)	1.07	(1.04–1.11)
Occupational class (EGP scheme, aged 30–69 years)								(Age adjusted)[c]	
Upper non-manual workers (I + II)	4,185,246	(15.2)	304	4.1	Reference			*Reference*	
Lower non-manual workers (III)	7,373,759	(26.8)	551	4.4	1.07			1.13[c]	(1.10–1.16)
Manual workers (V + VI + VIIa)	7,928,951	(28.8)	660	4.5	1.10			1.38[c]	(1.35–1.41)
Farmers (IVc + VIIb)	666,866	(2.4)	48	2.4	0.59			1.56[c]	(1.51–1.61)
Self-employed (IVa + b)	1,879,445	(6.8)	303	6.3	1.54			1.69[c]	(1.65–1.73)
Non-employee/unknown	5,470,536	(19.9)	1614	11.3	2.76			3.41[c]	(3.33–3.49)

ISCED: International Standard Classification of Education, EGP scheme: the Erikson-Goldthorpe-Portocarero scheme. 95% CI: 95% Confidence Interval, High (ISCED: 5–8): 2-year college/university graduation and more, Middle (ISCED: 3, 4): high school/technical professional school graduation, Low (ISCED: 1, 2): elementary school/junior high school graduation. [a]Age-standardised mortality rates (ASMR: per 100,000 person-year) were computed using the 2015 Japan standard population and data in 5-year age intervals. [b]Multivariable adjusted is a multivariable modified Poisson regression analysis with age, marital status, household size, educational level, areal deprivation index, and prefecture (n = 47) as covariates (Model 1). [c]Mortality rate ratio adjusting age.

Table 1: **Age-standardised mortality rate (ASMR: per 100,000 person-year) and mortality rate ratio from COVID-19 and all-cause by sociodemographic characteristics for men (the 2020 Japanese census-linked mortality database [death records between October 2020 and December 2022]: aged 30–89 years).**

	Population		COVID-19					All-cause	
			Number of deaths	ASMR[a]	ASMR ratio	Multivariable adjusted[b]		Multivariable adjusted[b]	
	n	(%)				Mortality rate ratio	95% CI	Mortality rate ratio	95% CI
Total	41,591,534		11,601	11.0					
Marital status									
Single	5,190,093	(12.5)	672	15.6	1.51	1.76	(1.61–1.92)	1.75	(1.71–1.79)
Married	27,752,517	(66.7)	4872	10.3	Reference	Reference		Reference	
Widow	5,401,145	(13.0)	5313	10.9	1.06	1.23	(1.17–1.30)	1.19	(1.17–1.22)
Divorced	3,247,779	(7.8)	744	14.0	1.36	1.53	(1.41–1.66)	1.42	(1.39–1.45)
Household size									
Living alone	5,914,932	(14.2)	2893	10.3	Reference	Reference	*(p for trend < 0.0001)*	Reference	*(p for trend < 0.0001)*
Two	14,184,762	(34.1)	4526	10.9	1.06	1.30	(1.22–1.38)	1.24	(1.21–1.27)
Three	10,000,164	(24.0)	2206	12.0	1.17	1.50	(1.40–1.61)	1.28	(1.24–1.31)
Four	7,307,830	(17.6)	1102	12.6	1.22	1.60	(1.48–1.74)	1.25	(1.21–1.29)
Five or more	4,183,846	(10.1)	874	11.8	1.15	1.69	(1.54–1.84)	1.20	(1.16–1.24)
Educational level									
High (ISCED: 5–8)	14,659,977	(35.2)	1061	9.3	Reference	Reference	*(p for trend < 0.0001)*	Reference	*(p for trend < 0.0001)*
Middle (ISCED: 3, 4)	17,236,000	(41.4)	4692	10.4	1.12	1.29	(1.20–1.39)	1.21	(1.19–1.24)
Low (ISCED: 1, 2)	5,235,206	(12.6)	4106	12.6	1.35	1.49	(1.38–1.61)	1.37	(1.34–1.40)
Unknown	4,460,351	(10.7)	1742	15.3	1.65	1.74	(1.60–1.89)	1.47	(1.43–1.51)
Areal deprivation index (municipality level)									
Quintiles 1 (least deprived)	7,674,995	(18.5)	2136	13.2	Reference	Reference	*(p for trend = 0.285)*	Reference	*(p for trend = 0.004)*
Quintiles 2	8,224,952	(19.8)	2116	10.8	0.82	0.98	(0.91–1.06)	1.02	(0.99–1.06)
Quintiles 3	8,340,412	(20.1)	2130	10.3	0.78	0.97	(0.89–1.04)	1.04	(1.004–1.08)
Quintiles 4	8,508,780	(20.5)	2254	10.0	0.76	0.93	(0.86–1.002)	1.04	(1.01–1.08)
Quintiles 5 (most deprived)	8,842,395	(21.3)	2965	11.3	0.86	0.97	(0.90–1.06)	1.05	(1.01–1.09)
Occupational class (EGP scheme, aged 30–69 years)								(Age adjusted)[c]	
Upper non-manual workers (I + II)	3,646,066	(12.6)	54	1.2	Reference			*Reference*	
Lower non-manual workers (III)	10,831,871	(37.6)	232	1.2	1.00			1.20[c]	(1.16–1.23)
Manual workers (V + VI + VIIa)	3,054,339	(10.6)	77	1.1	0.92			1.30[c]	(1.25–1.34)
Farmers (IVc + VIIb)	379,887	(1.3)	6	0.4	0.33			1.29[c]	(1.22–1.37)
Self-employed (IVa + b)	748,246	(2.6)	32	1.9	1.58			1.73[c]	(1.66–1.81)
Non-employee/unknown	10,170,414	(35.3)	761	2.9	2.42			3.18[c]	(3.08–3.27)

ISCED: International Standard Classification of Education, EGP scheme: the Erikson-Goldthorpe-Portocarero scheme. 95% CI: 95% Confidence Interval, High (ISCED: 5–8): 2-year college/university graduation and more, Middle (ISCED: 3, 4): high school/technical professional school graduation, Low (ISCED: 1, 2): elementary school/junior high school graduation. [a]Age-standardised mortality rates (ASMR: per 100,000 person-year) were computed using the 2015 Japan standard population and data in 5-year age intervals. [b]Multivariable adjusted is a multivariable modified Poisson regression analysis with age, marital status, household size, educational level, areal deprivation index, and prefecture (n = 47) as covariates (Model 1). [c]Mortality rate ratio adjusting age.

Table 2: **Age-standardised mortality rate (ASMR: per 100,000 person-year) and mortality rate ratio from COVID-19 and all-cause by sociodemographic characteristics for women (the 2020 Japanese census-linked mortality database [death records between October 2020 and December 2022]: aged 30–89 years).**

mortality rate ratios for men and women living with five or more people were 1.16 (95% CI: 1.14–1.19) and 1.20 (95% CI: 1.16–1.24), respectively, compared with those living alone (p for trend < 0.0001). Hence, a significant dose–response relationship was observed between household size and COVID-19 mortality rate ratios for both sexes. Educational level was significantly associated with COVID-19 mortality for both sexes (p for trend < 0.0001): for example, the multivariable-adjusted mortality rate ratios for low-educated men and women were 1.33 (95% CI: 1.27–1.40) and 1.49 (95% CI: 1.38–1.61), compared with highly-educated men and women, respectively. These trends were very comparable with those of all-cause mortality for both sexes.

The relationship between occupational class and COVID-19 mortality was not comparable to that between occupational class and all-cause mortality. For example, the COVID-19 ASMR ratios for male manual workers and male farmers were 1.10 and 0.59, compared with male upper non-manual workers, respectively. In contrast, for all-cause mortality, the age-adjusted mortality rate ratios for male upper non-manual workers and male farmers were 1.38 (95% CI: 1.35–1.41) and 1.56 (95% CI: 1.51–1.61), respectively, compared with male manual workers.

Regarding COVID-19 mortality at the prefecture level (as shown in Table 3), living in Osaka, Tokyo, Hyogo, Okinawa, and Hokkaido Prefectures was relatively high risk factor of COVID-19 mortality, compared with Tottori and Shimane Prefectures (San-in region, the western area facing the Sea of Japan on Japan's main island: area with the lowest COVID-19 mortality),

Prefecture		Men			Women		
No.	Name	ASMR[a]	Mortality rate ratio[b]	95% CI	ASMR[a]	Mortality rate ratio[b]	95% CI
	Total	28.6			11.0		
1	Hokkaido	35.9	4.11	(2.89–5.84)	15.6	3.53	(2.37–5.28)
2	Aomori	15.9	1.69	(1.15–2.50)	8.3	1.74	(1.12–2.70)
3	Iwate	15.1	1.61	(1.09–2.37)	5.6	1.21	(0.77–1.92)
4	Miyagi	15.7	1.69	(1.17–2.45)	7.2	1.53	(0.996–2.35)
5	Akita	15.2	1.68	(1.13–2.50)	6.4	1.38	(0.87–2.18)
6	Yamagata	17.6	1.88	(1.28–2.76)	5.9	1.24	(0.78–1.96)
7	Fukushima	19.9	2.12	(1.46–3.07)	5.7	1.20	(0.77–1.86)
8	Ibaraki	22.6	2.46	(1.72–3.53)	9.9	2.16	(1.43–3.27)
9	Tochigi	22.9	2.46	(1.70–3.55)	9.5	2.05	(1.34–3.14)
10	Gunma	21.1	2.33	(1.61–3.37)	9.0	2.00	(1.30–3.06)
11	Saitama	34.6	3.83	(2.70–5.43)	14.1	3.17	(2.13–4.72)
12	Chiba	28.9	3.18	(2.24–4.53)	11.4	2.55	(1.71–3.82)
13	Tokyo	41.7	4.61	(3.25–6.54)	15.5	3.52	(2.36–5.25)
14	Kanagawa	31.1	3.50	(2.47–4.97)	11.3	2.57	(1.72–3.83)
15	Niigata	11.3	1.21	(0.83–1.77)	3.7	0.79	(0.50–1.23)
16	Toyama	16.0	1.71	(1.14–2.55)	5.1	1.06	(0.65–1.72)
17	Ishikawa	17.2	1.90	(1.28–2.82)	5.4	1.17	(0.72–1.89)
18	Fukui	17.6	1.87	(1.25–2.81)	6.2	1.30	(0.80–2.12)
19	Yamanashi	16.1	1.77	(1.18–2.66)	5.8	1.35	(0.83–2.21)
20	Nagano	14.2	1.59	(1.09–2.30)	5.8	1.34	(0.87–2.07)
21	Gifu	22.5	2.42	(1.68–3.49)	7.0	1.49	(0.97–2.30)
22	Shizuoka	19.4	2.13	(1.49–3.04)	7.1	1.54	(1.02–2.33)
23	Aichi	32.5	3.58	(2.53–5.09)	12.4	2.72	(1.82–4.05)
24	Mie	20.6	2.27	(1.56–3.29)	8.4	1.83	(1.19–2.81)
25	Shiga	23.1	2.52	(1.73–3.68)	10.5	2.27	(1.47–3.52)
26	Kyoto	30.8	3.42	(2.39–4.90)	11.2	2.56	(1.69–3.88)
27	Osaka	53.2	5.93	(4.18–8.40)	21.5	4.90	(3.30–7.28)
28	Hyogo	40.8	4.62	(3.25–6.57)	16.0	3.71	(2.48–5.54)
29	Nara	30.0	3.41	(2.35–4.95)	9.2	2.09	(1.34–3.24)
30	Wakayama	20.2	2.26	(1.52–3.34)	6.8	1.60	(1.003–2.56)
31	Tottori[c]	9.3	Reference		4.8	Reference	
32	Shimane	11.4	1.22	(0.79–1.90)	3.6	0.76	(0.44–1.32)
33	Okayama	22.6	2.51	(1.73–3.64)	7.7	1.79	(1.17–2.76)
34	Hiroshima	18.7	2.12	(1.47–3.05)	8.2	1.93	(1.27–2.93)
35	Yamaguchi	16.4	1.90	(1.28–2.80)	6.9	1.62	(1.03–2.54)
36	Tokushima	17.4	1.95	(1.30–2.93)	5.2	1.16	(0.69–1.93)
37	Kagawa	17.3	1.91	(1.28–2.85)	6.1	1.41	(0.86–2.31)
38	Ehime	13.6	1.56	(1.05–2.31)	5.3	1.26	(0.79–2.00)
39	Kochi	24.5	2.67	(1.79–3.98)	7.7	1.72	(1.06–2.78)
40	Fukuoka	31.9	3.58	(2.52–5.10)	12.3	2.78	(1.86–4.16)
41	Saga	19.9	2.18	(1.46–3.24)	8.7	1.82	(1.14–2.91)
42	Nagasaki	16.2	1.81	(1.23–2.68)	5.4	1.22	(0.76–1.94)
43	Kumamoto	19.9	2.22	(1.53–3.21)	8.2	1.79	(1.17–2.76)
44	Oita	18.5	2.11	(1.42–3.14)	6.6	1.52	(0.94–2.44)
45	Miyazaki	19.6	2.22	(1.50–3.29)	8.9	1.99	(1.27–3.14)
46	Kagoshima	17.7	2.04	(1.39–2.98)	6.2	1.49	(0.95–2.35)
47	Okinawa	42.2	4.41	(3.06–6.37)	18.5	3.93	(2.57–6.01)

95% CI: 95% Confidence Interval. [a]Age-standardised mortality rates (ASMR: per 100,000 person-year) were computed using the 2015 Japan standard population and data in 5-year age intervals. [b]Multivariable adjusted is a multivariable modified Poisson regression analysis with prefecture (n = 47) as an explanatory variable and age, marital status, household size, educational level, and areal deprivation index, as covariates (Model 1). [c]Tottori prefecture had the lowest COVID-19 mortality for both sexes combined and was set as a reference.

Table 3: **Age-standardised mortality rate (ASMR: per 100,000 person-year) from COVID-19 and multivariable adjusted mortality rate ratio by 47 prefectures (the 2020 Japanese census-linked mortality database [death records between October 2020 and December 2022]: aged 30–89 years).**

after adjusting for sociodemographic characteristics. In addition, Niigata Prefecture was a low-risk prefecture, following Tottori and Shimane Prefectures.

Associations between COVID-19 mortality and the above-mentioned sociodemographic characteristics were consistent across both variant dominance periods, although some variations in mortality rate ratios were observed. Fig. 3A and B shows changes in COVID-19 mortality rate ratio by sociodemographic characteristics between 2021 and 2022. For example, the multivariable-adjusted mortality rate ratios for low-educated women in 2021 and 2022 were 1.55 [95% CI: 1.35–1.78] and 1.49 [95% CI: 1.35–1.65], respectively, compared with high-educated women (p for trend < 0.0001 for both periods). Household size was significantly associated with COVID-19 mortality, especially in 2022. For example, the multivariable-adjusted mortality rate ratios of men and women living with five or more people were 1.64 (95% CI: 1.50–1.80) and 1.78 (95% CI: 1.60–1.98), respectively, compared with men and women living alone (p for trend < 0.0001 for both sexes).

ADI (five categories) was associated with all-cause mortality for both sexes (p for trend < 0.0001, as shown in Tables 1 and 2). For example, the multivariable-adjusted mortality rate ratios for individuals living in the most deprived municipalities (ADI: Quintiles 5) was 1.07 (95% CI: 1.04–1.11) for men and 1.05 (95% CI: 1.01–1.09) for women, compared with individuals living in the least deprived municipalities (ADI: Quintiles 1). However, these trends clearly diverged from those of COVID-19 mortality. The multivariable-adjusted COVID-19 mortality rate ratios for individuals living in the most deprived municipalities were 0.95 (95% CI: 0.89–1.01) for men (p for trend = 0.069) and 0.97 (95% CI: 0.90–1.06) for women (p for trend = 0.285), compared with those living in the least deprived municipalities (Tables 1 and 2). The Poisson regression analysis with an interaction term (Model 2: Fig. 3C and D) indicated the heterogeneity of the association between ADI and COVID-19 mortality in the endemic metropolitan areas for men in 2022 (i.e., p for interaction between ADI and living in the endemic metropolitan areas for men = 0.024). Hence,

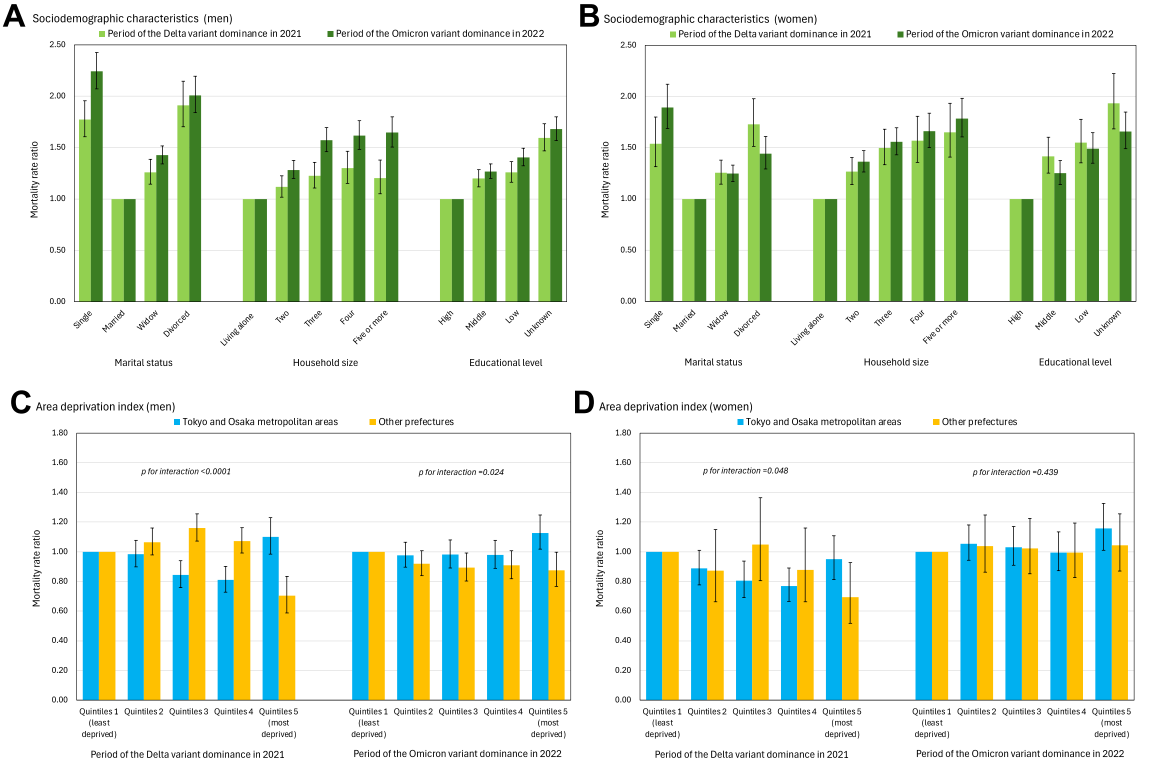

Fig. 3: Changes in COVID-19 mortality rate ratio by sociodemographic characteristics between 2021 (January–December) and 2022 (January–December), the 2020 Japanese census-linked mortality database: aged 30–89 years. Note: Panels (A) and (B); Multivariable modified Poisson regression analysis was performed with age, marital status, household size, educational level, areal deprivation index, and prefecture (n = 47) as covariates (Model 1). Panels (C) and (D); Multivariable modified Poisson regression analysis was performed with age, marital status, household size, educational level, areal deprivation index, and prefecture as covariates adding an interaction term between areal deprivation index (ordinal variables of Quintiles 1–5) and metropolitan areas (the Tokyo and Osaka metropolitan areas or none) (Model 2).

living in the most deprived municipalities of the endemic metropolitan areas was associated with higher COVID-19 mortality rate ratios in 2022 (e.g., men and women living in the most deprived municipalities: 1.13 [95% CI: 1.02–1.25] and 1.16 [95% CI: 1.01–1.33], respectively, compared with those living in the least deprived municipalities), whereas living in deprived municipalities in other prefectures was not associated with higher COVID-19 mortality rate ratios throughout both periods (e.g., men living in the most deprived municipalities: 0.88 [95% CI: 0.77–1.0002], compared with men living in the least deprived municipalities in 2022). Furthermore, in 2021, individuals living in the most deprived municipalities of other prefectures had lower COVID-19 mortality rate ratios compared with those living in the least deprived municipalities (e.g., men and women living in the most deprived municipalities: 0.70 [95% CI: 0.56–0.88] and 0.69 [95% CI: 0.52–0.93], respectively, compared with those living the least deprived municipalities).

Sensitivity analysis revealed consistent relationships between COVID-19 mortality and sociodemographic characteristics, even in analyses covering non-institutionalised and institutionalised Japanese aged 30 years and over. However, some variations in mortality rate ratios were observed (Supplementary Tables S3 and S4).

Discussion

This study showed that marital status (single or divorced) and low educational attainment were associated with increased COVID-19 mortality rates as well as all-cause mortality for the non-institutionalised population. In contrast, living with more household members was associated with a significant increase in the COVID-19 mortality rate, after controlling for other sociodemographic characteristics. These relationships were consistent across sexes and during both variant dominance periods (i.e., Delta variant dominance in 2021 and Omicron variant dominance in 2022). We found that living in the most deprived municipalities of the Tokyo and Osaka metropolitan areas was associated with increased COVID-19 mortality rates for both sexes in 2022; however, at the national level, area deprivation was not associated with increased COVID-19 mortality throughout the pandemic in Japan.

The trends in COVID-19 mortality rate according to marital status and educational level were very similar to those of all-cause mortality. However, a dose–response relationship was observed between household size and COVID-19 mortality for both sexes. Among men, COVID-19 ASMRs for individuals living alone were higher than those for individuals living with more than one person because marital status (a single person with high mortality rate is more likely to live alone: 39.8%, compared with married men living alone: 2.3%) is a confounder for the causal relationship between household size and COVID-19 cause-specific mortality. However, among women, COVID-19 ASMRs for individuals living alone were lower than those for individuals living with more than one person. For instance, grandchildren (e.g., high school or university students) and middle-aged family members may get infected and spread it to other individuals in the household, especially grandparents, who are at high risk of COVID-19 mortality due to underlying diseases, as a large household may comprise three generations or multiple children. These findings were comparable to previous studies showing that household composition, such as living with more family members and younger generations, was associated with increased COVID-19 mortality.[15–18] The results of the present study emphasise that COVID-19 mortality is generally high among single and divorced individuals. However, the health sector and large households should be aware of the potentially high mortality rate associated with emerging infectious diseases. In particular, the living conditions for large families in metropolitan areas (e.g., crowded housing and decreasing floor space due to rising rents) are considered health risk factors in densely populated cities worldwide.

In Japan, COVID-19 infections are more prevalent in urban areas,[20] and the Japanese government issued a state of emergency several times, mainly in populous prefectures such as Tokyo and Osaka.[1] For example, COVID-19 mortality was low in the Tohoku region (the northeast area of Japan's main island), where all-cause mortality rate is generally high.[29] This is related to the fact that the prefectures are geographically far from Tokyo and Osaka and the state of emergency declaration restricted people from travelling within the country,[1] which resulted in the COVID-19 infection not spreading significantly, except Hokkaido and Okinawa Prefectures (Japan's most popular resort areas). Tohoku region generally includes more deprived municipalities, compared with Tokyo. Therefore, ADI was not directly associated with COVID-19 mortality at the national level in Japan; however, the most deprived municipalities in the inner cities of the Tokyo and Osaka metropolitan areas had higher COVID-19 mortality rates than did less deprived municipalities in metropolitan areas (Fig. 3). These findings do not align with previous reports indicating that COVID-19 mortality rates are higher in areas of socioeconomic disadvantage than affluent areas in other countries.[4,7] These unique findings in Japan were missing in an ecological study conducted by prefecture level[19]; however, our census-linked mortality data shed light on the overall geographical aspects related to area deprivation in Japan. Regarding the occupational class, COVID-19 mortality was generally very low among the working-age generation in Japan; hence, the result should be interpreted with caution (Supplementary Table S2).

Sociodemographic patterns of COVID-19 mortality in Japan were consistent throughout the pandemic, except for ADI (Fig. 3), and varied slightly between sexes (e.g., time trend patterns or magnitude of inequalities). However, the reasons for these differences were unclear. These patterns were more consistent for women across periods, whereas among men (e.g., household size), they became more prominent during the dominance of the Omicron variant in 2022. This implies that this pattern emerged because the COVID-19 outbreak peaked after the summer of 2022 in Japan (Supplementary Figure S1), causing widespread infections and deaths in non-metropolitan prefectures,[20] thereby highlighting the sociodemographic patterns of existing health inequalities across the country.

The census-linked mortality database used in this study offers several advantages. First, it included data of 80 million Japanese citizens, with approximately 2 million death records, thus covering the largest Japanese cohort. Second, the census-linked mortality database provided a prospective individual-based analysis starting from the 2020 census, which eliminated the effect of numerator–denominator bias. In addition, our results showing socioeconomic inequalities in mortality in the early 2020s corresponded to those in the early 2010s for the Japanese populations, which revealed that individuals with the lowest education level had approximately 40% higher all-cause mortality rates than those with the highest education level.[23] The census-linked mortality database developed in this study is valuable and cost-effective, making it highly sustainable for careful monitoring of health inequalities in Japan. Although data linkage procedures are costly, high cost-effectiveness may be achieved by leveraging digitised administrative data, given the increasing data scalability in medicine and public health.

One key limitation of this study is the low census–death record linkage rate among those aged 85 years and older, which may have resulted in proportional underestimations of mortality. The census-linked mortality rate observed in this study was generally lower than that in the complete mortality registry, and this trend was most significant in women aged 85 years and older. This may have been because of specific causes of death (e.g., senility). We compared the all-cause and broad-cause ASMRs using a complete registry (Supplementary Table S1). Low mortality rates may be related to missing census–death record linkage owing to the possibility of linkage key changes and differences in sampled populations including only non-institutionalised Japanese populations, who are considered healthier (low mortality rate) than institutionalised populations. The results should be interpreted with caution. For example, COVID-19 mortality that occurred at the age of 90 years or older were excluded, but COVID-19 ASMRs (aged 30–89 years) were approximately 15% lower than those in the complete registry.

Our primary analyses were restricted to non-institutionalised Japanese aged 30–89 years; therefore, our findings should be interpreted for non-institutionalised individuals only. After considering mortality validations, we excluded institutionalised Japanese individuals who lived in geriatric health service facilities as of 1 October 2020. This exclusion was necessary because elements of linkage keys (e.g., marital status or birth month) from the census were generally inaccurate among those requiring daily care, especially the oldest old population. In addition, some institutionalised individuals were not required to change their residential address to that of the facility after admission. These factors caused missing census–death record linkages through linkage key changes, resulting in serious mortality underestimation among institutionalised Japanese individuals. For example, the multivariable-adjusted all-cause mortality rate ratios of institutionalised individuals were lower than those of non-institutionalised individuals living alone for both sexes in the sensitivity analysis (Supplementary Tables S3 and S4). Considering the generally high mortality among institutionalised individuals, this suggests an underestimation of the census-linked mortality database for institutionalised Japanese populations. COVID-19 cluster outbreaks in geriatric health service facilities were a significant public health concern in Japan. However, our results did not cover deaths from COVID-19 cluster outbreaks in geriatric health service facilities. More research is needed to clarify COVID-19 mortality patterns for institutionalised Japanese individuals, as the clinical backgrounds and infection patterns for institutionalised individuals (e.g., cluster outbreaks) may be different from those of individuals with community-acquired infections.

Another limitation of this study is that we could not consider COVID-19 incidence based on geographic and sociodemographic characteristics directly attributable to mortality. This is because there was a national active surveillance system for COVID-19 in Japan,[1] but the system did not cover detailed sociodemographic characteristics or report municipality-level COVID-19 incidence. Therefore, we could not discuss disease-specific fatality rates from SARS-CoV-2 infection by sociodemographic characteristics and regions. Moreover, we did not consider their COVID-19 vaccination history. The census covers nationality but not race or ethnicity; therefore, we did not include these characteristics, which are commonly included in studies conducted in other countries.[5] Finally, the current findings demonstrated the direct causes of COVID-19 mortality as defined by the MHLW. Further discussion is required when considering excess deaths in Japan.

Conclusions

In Japan, sociodemographic patterns of COVID-19 mortality for the non-institutionalised population related to marital status and education reflect underlying health inequalities—all-cause mortality patterns. However, area deprivation did not show a similar association and should be interpreted with caution, particularly in metropolitan contexts. Notably, residing in large households was uniquely associated with increased COVID-19 mortality, an uncommon feature among cause-specific mortality patterns. Careful monitoring is necessary to better understand health inequalities globally using census-linked mortality or health data, which is potentially cost-effective and highly sustainable. These findings offer important evidence for evaluating Japan's COVID-19 countermeasures and informing future public health strategies worldwide.

Contributors

All authors contributed to the data analysis and the concept and design of the study. HT and KK have accessed and verified the data. HT was responsible for the integrity of the data, accuracy of the data analysis, and the drafting of the manuscript. TN managed the area deprivation index dataset. All authors critically reviewed the manuscript. YK and KK supervised the study and provided administrative, technical, and material support. All authors accepted responsibility for the decision to submit for publication.

Data sharing statement

Data are not available from the authors due to data protection. Microdata from the census and vital statistics are potentially available from the MIC and MHLW through due procedures in Japan.

Editor note

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Declaration of interests

Authors do not have any conflicts of interest to declare.

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Appendix A. Supplementary data

Supplementary data related to this article can be found at https://doi.org/10.1016/j.lanwpc.2025.101609.

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