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Research paper

Area-level socioeconomic deprivation and suicide by restrictable method of death: Trends in Japan, 1995–2022

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ABSTRACT

Background: To establish an effective and equitable suicide prevention strategy, it is critical that we understand the distribution, according to area-level socioeconomic deprivation, of deaths by methods of suicide that are restrictable. We aimed to reveal this distribution and associated trends in Japan.
Methods: This serial cross-sectional study used vital statistics in Japan from 1995 to 2022. Area-level socioeconomic deprivation at municipality level was estimated by the Area Deprivation Index in Japan. Suicide by four restrictable methods—pesticide ingestion, jumping from a high place, intentional collision, and medication overdose—were identified based on vital statistics according to area-level socioeconomic deprivation.
Results: From 1995 to 2022, 738,810 suicides were observed, with 108,628 suicides by the four restrictable methods. Suicide rates by pesticide ingestion, jumping from a height, and medication overdose were higher in deprived areas than in non-deprived areas, while the suicide rate by intentional collision was higher in non-deprived areas than in deprived areas. Both suicide by pesticide ingestion and its inequality between deprived and non-deprived areas have continuously decreased since 2000. Suicide by jumping from a height and medication overdose have decreased since 2010, with widened inequality observed between deprived and non-deprived areas.
Conclusion: Area-level socioeconomic deprivation was associated with a higher suicide rate by pesticide ingestion, jumping from a height, and medication overdose while suicide rate by intentional collision was higher in non-deprived areas than in deprived areas. Integrating method restrictions tailored to residential characteristics into suicide prevention strategies may help promote health equity across areas.

1. Introduction

Establishing an equitable suicide prevention strategy is a pressing public health objective. Globally, over 720,000 people die by suicide every year (World Health Organization, 2021), with a disproportionate concentration in socioeconomically deprived areas (Cairns et al., 2017; Qian et al., 2023). Beyond the direct societal burden of suicide, each death affects more than 100 bereaved persons (Cerel et al., 2019) and is associated with a three-fold increase in risk of suicide in those bereaved (Hill et al., 2020). In Japan, although suicide prevention efforts have reduced the suicide rate in recent decades, more than 20,000 people still die by suicide every year, particularly in socioeconomically deprived areas ("e-Stat Portal Site of Official Statistics of Japan,", n.d.; Nakaya and Ito, 2020). As area-level socioeconomic deprivation is multi-faceted—comprising physical and social disadvantage, such as disproportionate access to healthy/unhealthy materials and places (Martikainen et al., 2004; Ribeiro, 2018; Sudhinaraset et al., 2016)—it may involve access to highly lethal methods. This accessibility could contribute to higher suicide risk in deprived areas, highlighting them as critical targets for equitable suicide prevention efforts.

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There is extensive evidence that restricting access to highly lethal suicide methods (methods restriction) effectively prevents death by those methods and has the potential to reduce the overall suicide rate (Gunnell et al., 2017; Lim et al., 2021; Pirkis et al., 2015; Zalsman et al., 2016). The bans on hazardous pesticides, such as organophosphate insecticides and paraquat, were associated with reductions in the suicide rate by pesticide ingestion, with an overall decrease in South Korea, Sri Lanka, Bangladesh, and China (Cha et al., 2016; Chowdhury et al., 2018; Knipe et al., 2017; Yan et al., 2023) and no change in overall suicides in Taiwan (Chang et al., 2022). Installing barriers such as fences at bridges and other areas of concern has been associated with an 86 % reduction in suicide at these areas, with only limited substitution effects at nearby sites (Pirkis et al., 2013). In Hong Kong, the installation of platform doors in one subway corporation reduced suicides by intentional collision on the railway tracks, with no evidence of an increase in suicides at the subway operated by other corporations (Law et al., 2009). A similar pattern was observed in Japan, where suicide at train platforms was reduced by 76 % after the installation of platform doors at the station (Ueda et al., 2015). Reductions in suicide by medication overdose were also observed in some countries after the introduction of pharmaceutical restrictions, including pack size limitation and withdrawal of some products from the market (Carlsten et al., 1996; Hawton et al., 2013, 2012; Nordentoft et al., 2007). For example, limiting the over-the-counter paracetamol pack size in the United Kingdom—to 32 tablets in pharmacies and 16 tablets for non-pharmacy sales—reduced suicide by paracetamol overdose by 43 % (Hawton et al., 2013). Given the effectiveness of methods restriction via legislative or policy changes, it is crucial to reveal how commonly these methods are used and to explore the potential differential impact of methods restriction on the suicide rate according to area-level socioeconomic deprivation. However, it remains unclear how suicides by restrictable methods are distributed according to area-level socioeconomic deprivation and how they have changed over time.

To address this knowledge gap, we conducted a nationwide serial cross-sectional study to describe suicide rates by restrictable methods, as well as the overall suicide rate, according to area-level socioeconomic deprivation in Japan and changes in levels from 1995 to 2022. Although gas and gunshot are also restrictable methods (Lim et al., 2021), domestic gas and motor vehicle exhaust were detoxified in the 1980s, and the proportion of suicide by gunshot represented a small fraction of overall suicide in Japan (5 cases [0.02 %] in 2022) ("e-Stat Portal Site of Official Statistics of Japan," n.d.); thus, they were not part of our primary focus. To explore how individual and residential characteristics influence the selection of suicide methods, we also drew the distribution stratified by age, sex, and urbanicity. Although hanging is a leading method of suicide in Japan (14,985 cases [70.5 %] in 2022; "e-Stat Portal Site of Official Statistics of Japan," n.d.), as it is difficult to restrict access to hanging in the community, it is not included in this study. Nonetheless, the four potentially restrictable methods still account for a substantial number of suicides (3156 cases [14.9 %] in 2022) ("e-Stat Portal Site of Official Statistics of Japan," n.d.). In this context, understanding the distribution of suicide by restrictable methods may provide critical insights for policymakers in designing an effective and equitable suicide prevention strategy, which may enhance the downward trend of suicide in Japan since 2010.

2. Methods

2.1. Design, setting, and population

This nationwide serial cross-sectional study used vital statistics in Japan from 1995 to 2022, collected by the Ministry of Health, Labour and Welfare (MHLW). MHLW collects the death certificates of all residents in Japan. Each death certificate contains information about the date, place, and cause of death, as well as basic demographics, such as age, sex, and place of residence (at the municipality level). To measure area-level socioeconomic deprivation reliably, we excluded municipalities with a population of less than 50 households. As the cause of death was recorded based on the *International Statistical Classification of Diseases and Related Health Problems, Tenth Revision* (ICD-10) in Japan, we used data from 1995 to 2022, the most recent available year. The sex and 5-year age specific population size of the municipality was collected from the national census ("e-Stat Portal Site of Official Statistics of Japan," n.d.). As the census is conducted every five years in Japan, we applied linear interpolation to estimate the population size between the census years (see eMethod 1 in Supplementary Material).

2.2. Variable measurement

Area-level socioeconomic deprivation was measured by the Areal Deprivation Index in Japan (ADI) (Nakaya et al., 2014). Using the national census in 2000, we calculated ADI at municipality level, and categorised municipalities into deprived (ADI $\geqq$ the median) and non-deprived areas (ADI $<$ the median) (see eMethod 2 in Supplementary Material).

Suicides were identified based on death certificates, which included the cause of death based on the ICD-10 code (X60-X84 and Y87). We also categorised suicide by restrictable methods based on ICD-10 codes; pesticide ingestion (X68), jumping from a height (X80), intentional collision (jumping or lying down in front of moving objects; X81), and medication overdose (X60-X64).

Urbanicity in the municipality was measured based on the proportion of people living in densely inhabited districts (%DID) (Statistics Bureau of Japan, 2025). We categorised each municipality into urban (% DID $>$90 %) and non-urban (%DID $\leqq$ 90 %).

2.3. Statistical analysis

We described municipality characteristics in 2000 according to area-level socioeconomic deprivation levels. We also calculated overall suicide rates and suicide rates by the four restrictable methods in each year from 1995 to 2022, stratified by area-level socioeconomic deprivation (deprived or non-deprived areas). In this calculation, we substituted person-years by the mid-year population size. Suicide inequality was assessed on both additive and multiplicative scales, i.e., we calculated the suicide rate differences (RD) and suicide rate ratios (RR) between deprived and non-deprived areas, with 95 % confidence intervals (CI). We further stratified the analysis by sex (men or women), age (aged $<$40 years or aged $\geqq$ 40 years], and urbanicity in the municipality (urban or non-urban).

To account for the influence of changing the population structure during the study period, we applied the direct standardisation method using the population in 2015 as the standard and calculated sex-age-standardised suicide rates. We also calculated the suicide rate by all other methods: gas poisoning (X67), other chemical poisoning (X65, X66, and X69), hanging and suffocation (X70), drowning (X71), gunshot (X72-X74), other (X75-X79, X82-X84, and Y87). All statistical analyses and data management were conducted from August 2024 to March 2025 using R Statistical Software (v4.3.0; R Core Team (R Core Team, 2023)).

3. Results

From 1995 to 2022, 738,810 persons died by suicide, with 108,628 (14.7 %) suicides by four restrictable methods. Deprived municipalities were more likely to be smaller, less densely populated, and have more older residents, fewer non- Japanese nationals, more single-person households, more unemployed workers and workers engaged in primary industry, fewer workers in sales, services, clerical technical, and managerial work, and fewer persons with higher education attainment (Table 1; Fig. S1 in Supplementary Material). The suicide rate in deprived areas was higher than that in non-deprived areas (suicide rate in deprived areas = 23.1/ 100,000 person-years, suicide rate in non-

Table 1
Characteristics of municipalities by area-level socioeconomic deprivation in 2000, median (interquartile range).

Characteristic	Deprived areas	Non-deprived areas
	N = 1155	*N* = 701
Population size, n	22,137 (7843, 61,502)	46,606 (18,992, 115,993)
Living in DID, (%)	0.0 (0.0, 48.0)	39.3 (0.0, 76.3)
Age (%)		
0–14 years	14.4 (13.0, 15.6)	15.1 (14.2, 16.2)
15–64 years	61.8 (58.1, 65.3)	67.6 (63.5, 71.0)
65 years or older	23.7 (19.4, 28.1)	17.1 (13.9, 21.4)
Sex (%)		
Men	47.9 (47.1, 48.9)	49.0 (48.2, 50.0)
Women	52.1 (51.1, 52.9)	51.0 (50.0, 51.8)
Nationality other than Japanese (%)	0.3 (0.2, 0.7)	0.7 (0.4, 1.2)
Single household (%)	22.6 (18.2, 27.3)	18.4 (14.2, 24.8)
Marital status (%)		
Married	63.0 (60.9, 64.8)	63.2 (61.2, 64.7)
Unmarried	37.0 (35.2, 39.1)	36.8 (35.3, 38.8)
Renter household (%)	24.7 (15.9, 35.9)	23.6 (14.0, 35.5)
Unemployment rate (%)	4.2 (3.0, 5.3)	3.9 (3.2, 4.6)
Temporary workers (%)	10.4 (9.2, 12.5)	10.4 (9.3, 11.7)
Occupation (%)		
Agriculture, forestry, and fishery	13.6 (5.5, 21.9)	4.5 (1.8, 9.3)
Production and transport	35.1 (30.2, 39.7)	36.7 (29.7, 4.24)
Sales and service	20.6 (17.1, 25.0)	22.8 (19.2, 26.8)
Clerical, technical, and managerial	28.2 (24.9, 32.3)	33.4 (28.9, 39.3)
Education attainment (%)		
Low	37.8 (29.0, 47.0)	26.2 (18.1, 34.1)
Middle	45.0 (40.3, 48.7)	46.2 (42.7, 49.0)
High	15.1 (11.9, 19.9)	23.6 (17.7, 31.6)

DID, densely inhabited district.
Education attainment was classified into three levels: low (elementary school/junior high school graduate), middle (high school graduates, and high (technical professional school graduate/2-year college graduate/university graduate/graduate school graduate).

deprived areas = 19.5/100,000 person-years).

3.1. Trend of overall suicide rate and its inequality by area-level socioeconomic deprivation

In both deprived and non-deprived areas, the overall suicide rate rose sharply in 1998 and remained high until 2009, after which there was a continuous decrease from 2010 to 2019. However, the rate rose again after 2020. The difference in suicide rate between deprived and non-deprived areas widened in 1998, while the suicide rate ratio remained at the same level. Inequality in suicide rates remained stable until 2009 but decreased after 2010, with a temporary exacerbation in 2021 (Fig. 1; Table S1 in Supplementary Material).

3.2. Trend in suicide rates by restrictable methods

The suicide rate by pesticide ingestion and its inequality between deprived and non-deprived areas decreased continuously after 2000 (deprived vs. non-deprived areas: in 1995, RD = 0.18 [95 % CI 0.09, 0.27], RR = 1.31 [95 % CI 1.14, 1.50]; in 2022, RD = 0.02 [95 % CI -0.02, 0.05], RR = 1.18 [95 % CI 0.82, 1.72]). The suicide rate by jumping from a height reduced after 1999, while its inequality widened. Moreover, the suicide rate in deprived areas sharply rose in 2022, and thus, the inequality further widened in 2022 (deprived vs. non-deprived areas: in 1995, RD = 0.06 [95 % CI -0.08, 0.21], RR = 1.04 [95 % CI 0.95, 1.13]; in 2022, RD = 0.36 [95 % CI 0.20, 0.51], RR = 1.22 [95 % CI 1.12, 1.33]). The suicide rate by intentional collision and its inequality remained at the same level throughout the study period. In contrast to the other two restrictable methods, the rate was higher in non-deprived areas than in deprived areas (deprived vs. non-deprived areas: in 1995 RD = −0.21 [95 % CI −0.30, −0.13], RR = 0.71 [95 % CI 0.62, 0.82]; in 2022, RD = −0.24 [95 % CI −0.32, −0.17], RR = 0.59 [95 % CI 0.49, 0.70]). The suicide rate by medication overdose decreased after 2009, which is slightly greater in non-deprived areas than in deprived areas. The overall suicide rate rose after 2020, particularly in deprived areas (deprived vs. non-deprived areas: in 1995, RD = 0.03 [95 % CI −0.03, 0.09], RR = 1.12 [95 % CI 0.91, 1.37]; in 2022 RD = 0.05 [95 % CI −0.02, 0.11], RR = 1.15 [95 % CI 0.95, 1.41]. (Fig. 2 and Table 2; Table S2 in Supplementary Material).

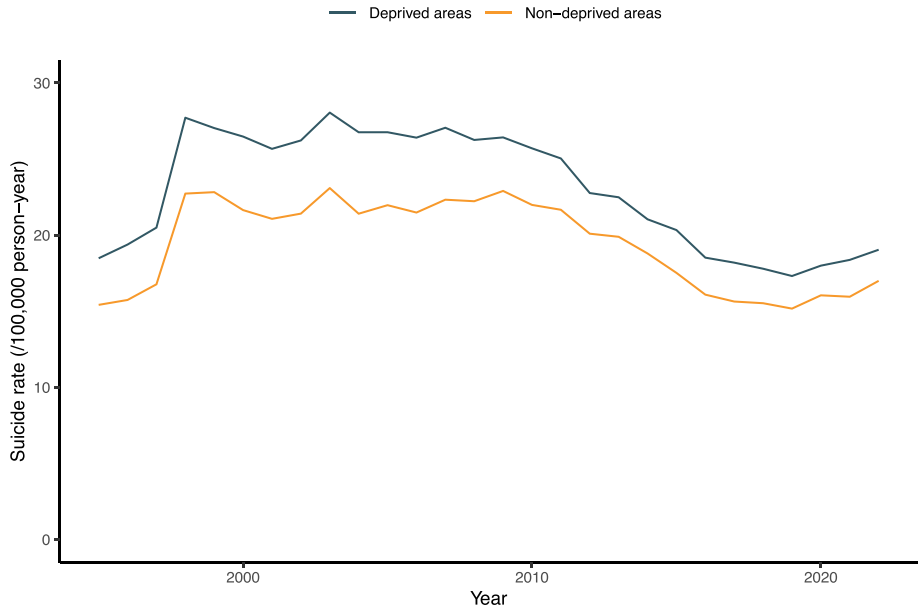

Fig. 1. Trends of suicide rate in Japan according to area-level socioeconomic deprivation, 2000–2022.

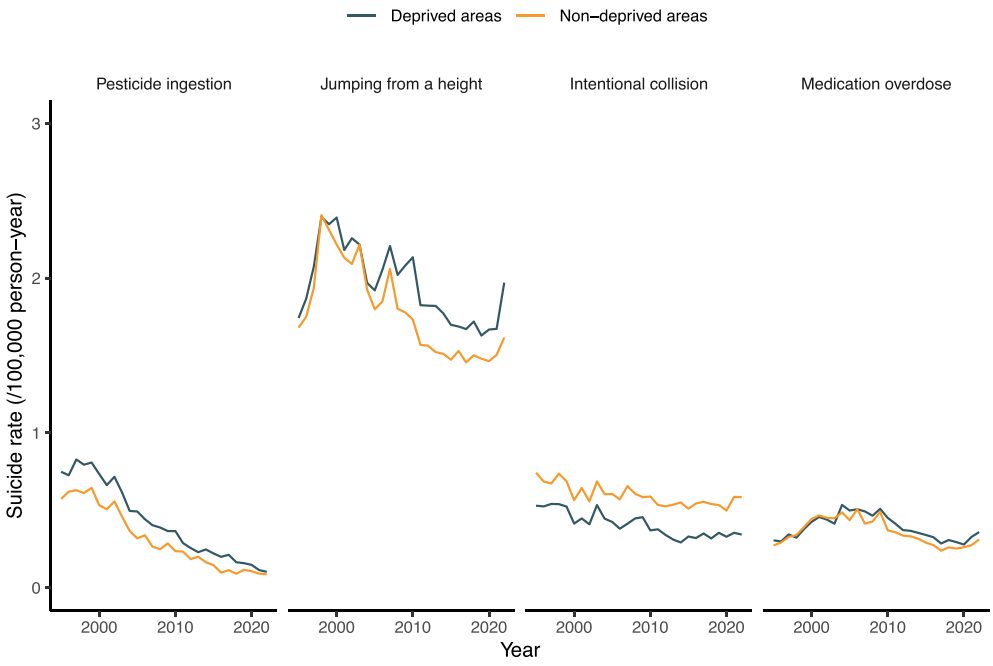

Fig. 2. Trends of suicide rate by method in Japan according to area-level socioeconomic deprivation, 2000–2022.

Table 2
Trends of suicide rate (/100,000 person-years) by method in Japan according to area-level socioeconomic deprivation, 2000–2022.

	Overall suicide		Pesticide ingestion (X68)		Jumping from a height (X80)		Intentional collision (X81)		Medication overdose (X60-X64)	
Year	Deprived areas	Non-deprived areas	Deprived areas	Non-deprived areas	Deprived areas	Non-deprived areas	Deprived areas	Non-deprived areas	Deprived areas	Non-deprived areas
1995	18.48	15.42	0.75	0.57	1.74	1.68	0.53	0.74	0.31	0.27
1996	19.38	15.74	0.73	0.62	1.87	1.75	0.53	0.69	0.30	0.29
1997	20.50	16.77	0.83	0.63	2.07	1.94	0.54	0.67	0.34	0.33
1998	27.72	22.73	0.79	0.61	2.40	2.41	0.54	0.74	0.32	0.34
1999	27.04	22.83	0.81	0.64	2.35	2.31	0.52	0.69	0.38	0.39
2000	26.48	21.65	0.73	0.53	2.39	2.22	0.41	0.57	0.43	0.44
2001	25.67	21.07	0.66	0.51	2.18	2.13	0.45	0.64	0.46	0.47
2002	26.22	21.41	0.72	0.56	2.26	2.09	0.41	0.56	0.44	0.45
2003	28.05	23.09	0.62	0.46	2.22	2.22	0.53	0.69	0.41	0.45
2004	26.76	21.41	0.50	0.37	1.97	1.93	0.45	0.60	0.53	0.49
2005	26.76	21.97	0.49	0.32	1.92	1.80	0.42	0.61	0.50	0.44
2006	26.41	21.49	0.44	0.34	2.05	1.85	0.38	0.57	0.51	0.51
2007	27.06	22.33	0.40	0.26	2.21	2.06	0.41	0.66	0.49	0.41
2008	26.25	22.23	0.39	0.25	2.02	1.80	0.45	0.61	0.47	0.43
2009	26.42	22.90	0.37	0.29	2.08	1.78	0.46	0.58	0.51	0.49
2010	25.70	21.99	0.37	0.24	2.13	1.73	0.37	0.59	0.45	0.37
2011	25.04	21.67	0.29	0.23	1.83	1.57	0.38	0.53	0.41	0.36
2012	22.77	20.10	0.26	0.18	1.82	1.56	0.34	0.53	0.37	0.34
2013	22.49	19.89	0.23	0.20	1.82	1.52	0.31	0.54	0.37	0.33
2014	21.04	18.80	0.25	0.16	1.77	1.51	0.29	0.55	0.35	0.32
2015	20.33	17.52	0.22	0.15	1.70	1.47	0.33	0.51	0.34	0.29
2016	18.52	16.09	0.20	0.10	1.69	1.53	0.32	0.54	0.33	0.27
2017	18.19	15.64	0.21	0.11	1.67	1.46	0.35	0.55	0.29	0.24
2018	17.79	15.53	0.16	0.09	1.72	1.50	0.32	0.54	0.31	0.26
2019	17.31	15.17	0.16	0.12	1.63	1.48	0.35	0.53	0.29	0.25
2020	18.00	16.04	0.15	0.11	1.67	1.46	0.33	0.50	0.28	0.26
2021	18.37	15.95	0.11	0.09	1.67	1.50	0.35	0.59	0.33	0.27
2022	19.04	17.00	0.10	0.09	1.97	1.62	0.34	0.59	0.36	0.31

3.3. Subgroup analysis by sex, age, and urbanicity

Our subgroup analysis showed that the suicide rate by pesticide ingestion was higher among men, those aged ≧ 40 years, and those living in non-urban areas. Similarly, the suicide rate by jumping from a height was higher among men and those aged ≧ 40 years, but, unlike suicide by pesticide ingestion, it was also higher among those living in urban areas than in non-urban areas. Notably, the suicide rate by jumping from a height rose sharply among those aged <40 years after 2020 and reached the same level as those aged ≧ 40 years in 2022. This rise among those aged <40 years was more prominent in deprived areas than non-deprived areas. The suicide rate by intentional collision was higher among those living in urban areas. As well as suicide by jumping from a height, an upward trend in intentional collision was observed

among those aged <40 years, but this rise started before 2020. The suicide rate by medication overdose was higher among those aged <40 years and in urban areas. Additionally, the suicide rate by medication overdose among those aged <40 years rose after 2020. (Fig. 3; Table S3, Table S4, and Table S5 in Supplementary Material).

3.4. Additional analysis

The sex-age standardised suicide rate and its inequality showed qualitatively similar results while suicide rates before 2015 were slightly higher than crude suicide rates, reflecting a change in the population structure (Fig. S3, Fig. S4, Table S6, and Table S7 in Supplementary Material).

4. Discussion

This nationwide serial cross-sectional study found that area-level socioeconomic deprivation was associated with a higher overall suicide rate as well as suicide by pesticide ingestion, jumping from a height, and medication overdose. Conversely, suicide by intentional collision

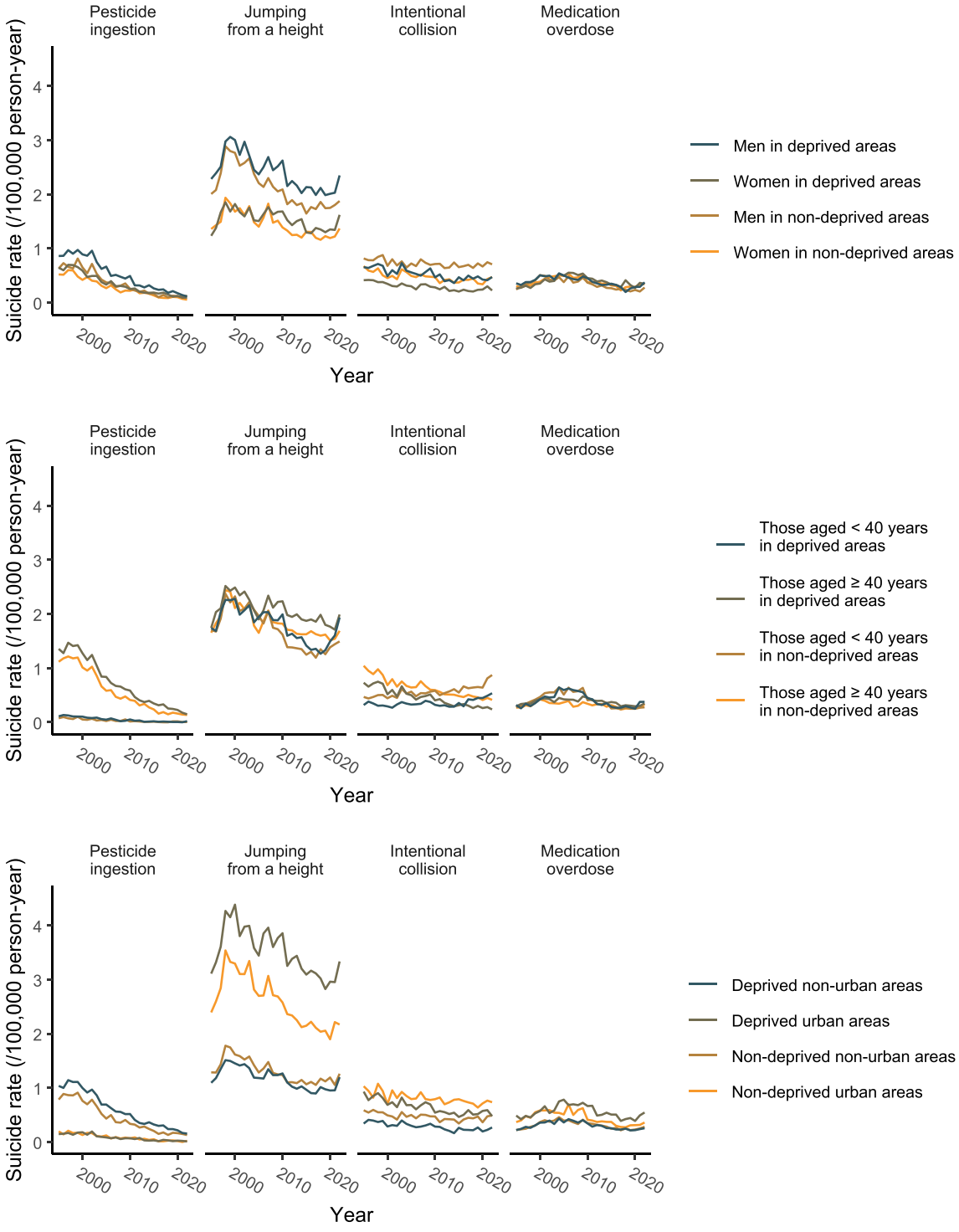

Fig. 3. Trends of suicide rate by method in Japan according to area-level socioeconomic deprivation and age, gender, and urbanicity, 2000–2022.

was more common in non-deprived areas than in deprived areas. We also found that continuous decreases in suicide by pesticide ingestion and its inequality from 1999, and slight decreases in suicide by jumping from a height and medication overdose from 2010 to 2019—though with widening inequality between deprived and non-deprived areas after 2020.

4.1. Overall suicide

We found that area-level socioeconomic deprivation was associated with a higher overall suicide rate from 1995 to 2022, in line with previous systematic reviews (Cairns et al., 2017; Qian et al., 2023). We also found that the suicide inequality between deprived and non-deprived areas decreased after 2010, although it temporarily exacerbated in 2021—aligning with an online survey reporting a higher prevalence of new-onset suicide ideation in deprived areas during the COVID-19 pandemic (Okubo et al., 2021). In 2009, the Japanese government established an emergency fund—Emergency Fund for Strengthening Regional Suicide Prevention (Ministry of Health, Labour and Welfare, 2025)— in response to the persistently high suicide rate since the 1998 economic recession. Using this fund, each local prefecture designed suicide prevention plans, tailored to regional needs, by selecting from five options proposed by the national government: support for face-to-face counselling services, support for a telephone helpline, human resource development, public awareness activity, and suicide prevention initiatives undertaken by local government. While both the individual and combined impact of these measures remain to be fully evaluated, our study suggests that the suicide prevention action in 2010 and subsequent efforts and initiatives have contributed to the overall decreases in suicide rate and its inequity across areas.

4.2. Suicide by restrictable methods

We found that suicide by pesticide ingestion, jumping from a height, and medication overdose were more common in deprived areas than in non-deprived areas. Although previous studies suggested disproportionate access to healthy and unhealthy resources may explain the higher suicide rate in deprived areas (Martikainen et al., 2004; Ribeiro, 2018; Sudhinaraset et al., 2016), evidence is limited as to whether the suicide rates by restrictable methods are higher in deprived areas. This study filled this gap, elucidating the disproportionate concentration of such suicide risk in deprived areas. However, as restrictable methods represented only 14.7 % of all suicides, methods restriction should be integrated with individual, clinical, interpersonal, and social approaches. For example, it is essential to reduce the cognitive availability of less restrictable methods, such as hanging, through appropriate media reporting and prevention activities targeting interpersonal and social media communication (Florentine and Crane, 2010; Pirkis et al., 2024; World Health Organization, 2023). Moreover, our study showed that suicide rates by methods with limited restrictions—jumping from a height, intentional collision, and medication overdose—increased after the COVID-19 pandemic, but suicide rates by pesticide ingestion did not show a similar increase. These findings may indicate the potential robustness of method restrictions in mitigating external influences, including the COVID-19 pandemic (Anzai et al., 2022; Yoshioka et al., 2022), and their long-term protective effect for preventing suicide by the restricted method.

4.3. Pesticide ingestion

We found a continuous decline in suicide by pesticide ingestion, following the 1999 ban on paraquat products—a highly hazardous pesticide commonly used for suicides in Japan (Ito and Nakamura, 2008). This pattern was consistent with previous studies in South Korea, Bangladesh, Sri Lanka, Taiwan, and China (Cha et al., 2016; Chang et al., 2022; Chowdhury et al., 2018; Knipe et al., 2017; Yan et al., 2023). Additionally, we found a continuous decline in suicide inequality by pesticide ingestion across deprived and non-deprived areas after the ban on paraquat products, which supported method restriction as an equitable intervention. We also found that it took more than 20 years for the total effect of the ban to be evident. However, we found no clear decrease in the overall suicide rate after 1999, in line with a study in Taiwan (Chang et al., 2022). This is in part because pesticide ingestion represents a small proportion of all suicide in Taiwan and Japan (2.9 % [905 cases] in Japan in 1999, Table S2 in Supplementary Material; 12 % in Taiwan (Chang et al., 2022)), in contrast to other countries (e.g., 16 % in South Korea, 40 % in Bangladesh, and $>$ 60 % in Sri Lanka (Gunnell et al., 2017)). Although we found no evidence of methods substitution—a coincident increase in suicide by other non-restricted methods following restriction, – we must acknowledge that emerging lethal methods could offset the reduction, as observed in India (Arya et al., 2021). Our subgroup analysis showed that the suicide rate by pesticide ingestion was higher in non-urban areas, possibly due to the original purpose of pesticides in agriculture. Given the overlap between area-level socioeconomic deprivation and rurality, the increased accessibility of hazardous pesticides in rural areas may have contributed to a higher suicide rate by pesticide ingestion in deprived areas.

4.4. Jumping from a height

We found that suicide by jumping from a height decreased slightly from 2010 to 2019, with widening inequality. Although the General Principles of Suicide Countermeasures Policy has recommended safety enhancements at areas of concern, including at jumping sites since 2007 (Ministry of Health, Labour and Welfare, 2022), installing physical barriers at such areas is often expensive, thereby impeding their implementation, despite their long-term cost-effectiveness (Atkins Whitmer and Woods, 2013; Bandara et al., 2022). Together with the limited financial capability of each local government, particularly in deprived areas, access to such hotspots may remain higher in deprived areas than in non-deprived areas. Additionally, our subgroup analysis showed that the suicide rate by jumping from a height was higher in urban than in non-urban areas. Given the global trend of increasing urbanisation (United Nations, 2018), our study highlighted the pressing need to design safer high places. Our subgroup analysis also showed that, among those aged $<$40 years, the suicide rate by jumping from a height rose sharply after 2020, particularly within deprived areas. Therefore, in the Japanese context, enhancing safety at high points is crucial for preventing premature death by suicide and ameliorating the existing health inequity.

4.5. Intentional collision

In contrast to the other restrictable methods, we found a higher suicide rate by intentional collision in non-deprived areas than in deprived areas. We also found that suicide by intentional collision is more common in urban than non-urban. This may reflect the more developed transport networks in non-deprived and urban areas. The number of platform doors in Japan doubled in the last decade (Ministry of Land, Infrastructure, Transport and Tourism, 2025) but despite this, and their potential effectiveness for preventing suicide at stations (Law et al., 2009; Ueda et al., 2015), we found no clear evidence of a reduction in suicide rate by intentional collision. As stations are often located near each other, particularly in non-deprived urban areas, people may die by suicide at nearby stations without platform doors, i.e. place substitution. Further studies are warranted to investigate whether place substitution occurs after platform door installation and identify strategies to optimise the preventive impact of the installation.

4.6. Medication overdose

We found a decreased trend in suicide by medication overdose from

2010 to 2019, particularly in non-deprived areas. However, it increased after 2020, particularly among those aged <40 years and in deprived urban areas. Although the underlying mechanism remains unclear, increased access to lethal medications (Ribeiro, 2018) the physical and social barriers to psychological care (Levesque et al., 2013), as well as heightened psychological distress (Ludwig et al., 2012; Okubo et al., 2021), may explain this greater vulnerability to suicide by medication overdose in deprived areas than in non-deprived areas. Given the reported effectiveness of pharmaceutical restrictions for preventing suicide by medication overdose (Carlsten et al., 1996; Hawton et al., 2013, 2012; Nordentoft et al., 2007), further restriction of lethal medications is a currently available solution. Additionally, investigating how and why suicide by medication overdose has recently increased in deprived areas, particularly among younger people and those in urban areas, should provide insights for integrating pharmaceutical restriction with psychological and psychiatric care.

4.7. Limitations

Our study has several limitations. First, it is not immune to suicide misclassification. Although we relied on national vital statistics and there is no evidence of the relationship between suicide and death due to unknown intent or cause (Matsubayashi and Ueda, 2022), identifying suicide is generally difficult (Schmeckenbecher et al., 2024). Moreover, the autopsy rate in Japan varies by area (National Police Agency, 2025), which could result in different misclassification rates across areas, leading to biased estimates of suicide inequality. Second, we could not capture the actual residential socioeconomic deprivation as we measured area-level socioeconomic deprivation using administrative boundaries which do not always align with residential areas. Third, this ecological study may suffer from confounding by individual- and area-level factors, such as physical and mental health conditions and accessibility to social supports (Favril et al., 2023; Wyllie et al., 2025). Moreover, our study provided limited insights into the underlying mechanisms at individual level. Future studies are warranted to consider a thorough set of individual- and area-level factors, using individual-level records. Lastly, our findings have limited transportability to other settings as the physical and cognitive availability of lethal methods vary by regions and change over time (Florentine and Crane, 2010). Further studies are warranted to develop frameworks for tailoring and adapting suicide prevention strategies to different global contexts.

5. Conclusion

Area-level socioeconomic deprivation was associated with a higher suicide rate by pesticide ingestion, jumping from a height, and medication overdose, as well as overall suicide rate while suicide rate by intentional collision was higher in non-deprived areas than in deprived areas. Inequality in suicide rate by pesticide ingestion continuously decreased after the 1999 national ban on paraquat products. Inequality in the suicide rate by jumping from a height and medication overdose widened after 2020. Integrating method restrictions tailored to residential characteristics into suicide prevention strategies may help promote health equity across areas.

CRediT authorship contribution statement

Yoshikazu Komura: Writing – original draft, Investigation, Conceptualization. **Naoki Kondo:** Writing – review & editing, Conceptualization. **Kunihiko Takahashi:** Writing – review & editing, Conceptualization. **Tomoki Nakaya:** Writing – review & editing, Conceptualization. **Rory C. O'Connor:** Writing – review & editing, Conceptualization. **Yuri Ito:** Writing – review & editing, Supervision, Conceptualization.

Informed consent

Informed consent for participants was waived because all data used in the study were anonymized by a third-party data provider.

Ethics approval

The institutional review board of Osaka Medical and Pharmaceutical University approved all study procedures (approval number: 2567-3). All study procedures were performed in accordance with the Declaration of Helsinki.

Declaration of Generative AI and AI-assisted technologies in the writing process

During the course of preparing this work, the authors used ChatGPT (OpenAI) for the purpose of grammar check. Following the use of this tool/service, the authors formally reviewed the content for its accuracy and edited it as necessary. The authors take full responsibility for all the content of this publication.

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Declaration of competing interest

All authors have completed the ICMJE uniform disclosure form (available on request from the corresponding author) and declare that they have no conflicts of interest to disclose.

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The analysis and conclusions presented are solely those of the authors and do not represent the official views of the Ministry of Health, Labour and Welfare.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.jad.2025.120442.

Data availability

The data used in this study are available from the Ministry of Health, Labour and Welfare; however, they were accessed under a specific approval for the current study and are therefore not publicly available.

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