Suicide and Types of Agriculture: A Time-Series Analysis in Japan

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Objective: In recent years, rural areas have reported higher suicide rates than urban areas worldwide. Although agricultural activity is a key characteristic of many rural areas, rurality may also have heterogeneous qualities based on the type of agriculture pursued. However, to date, no study has examined potential linkages between suicide rate and types of agriculture.

Method: In this study, we used 1983–2007 annual time-series data of the standardized mortality ratio (SMR) of suicide and product-specific agricultural outputs in Japanese municipalities to shed light on this phenomenon. We conducted a multilevel linear regression analysis, taking into account a hierarchical structure of the time-series data, limiting our analysis to municipalities where agricultural land use was high.

Results: Our multilevel analysis showed that the animal husbandry output was positively associated with suicide SMR in both women and men, with a stronger relationship among women, whereas no association was observed in agricultural crop output. Temporal analysis showed that the association could be observed consistently throughout the period between 1983 and 2007.

Conclusions: This study raises the possibility that the industrial and cultural characteristics of communities that rely on animal husbandry may be associated with an increased risk of suicide.

HIGHLIGHTS

- Suicide rates are higher in areas where animal husbandry is active
- The association between husbandry and suicide was observed in both genders
- No association between agricultural crop production and suicide was observed
- The suicide rate trend by type of agriculture did not change between 1983 and 2007

- Industrial and cultural aspects of livestock farming may explain suicide risks

Suicide has long been an important public health issue worldwide. Every year, nearly 800,000 people across the world kill themselves (World Health Organization [WHO], 2016). Determinants of suicide vary from individual biological and psychiatric traits and interpersonal relationships to contextual or place characteristics at the community level, as well as more macrosocial levels (Durkheim, 1897; Fässberg et al., 2012; Sinyor, Tse, & Pirkis, 2017; Stark, Riordan, & Connor, 2011). The social characteristics of communities and society, including macroeconomic fluctuations, area-level socioeconomic disadvantage, built environment, social capital, policy, and culture may affect individual health (Cairns, Graham, & Bambra, 2017; Hiyoshi, Kondo, & Rostila, 2018; Rehkopf & Buka, 2006; Samaritans, 2017; Wada et al., 2012). Hence, a better understanding of these "place effects" may allow the creation of more effective public health initiatives to promote suicide prevention (Cummins, Curtis, Diez-Roux, & Macintyre, 2007; Macintyre, Ellaway, & Cummins, 2002).

In many countries, evidence has suggested that suicide rates in rural areas are higher than those in urban areas; moreover, the urban/rural gap has widened in recent years (Chang et al., 2011; Cheung, Spittal, Pirkis, & Yip, 2012; Hirsch, 2006; Hirsch & Cukrowicz, 2014; Levin & Leyland, 2005; Otsu, Araki, Sakai, Yokoyama, & Scott Voorhees, 2004; Singh & Siahpush, 2002; Yamamoto, 1992). The suicide risk of male farmers has been shown to be higher than that of other occupations, including clerical workers, both in Japan and in other industrialized countries (Kagamimori et al., 2004; Klingelschmidt et al., 2016; Milner, Spittal, Pirkis, & LaMontagne, 2013; Suzuki, Kashima, Kawachi, & Subramanian, 2013; Wada, Eguchi, Prieto-Merino, & Smith, 2016). Although agricultural activity is a key characteristic of many rural areas, rurality may also have heterogeneous qualities including job

characteristics, history, culture, and modes of interaction among individuals and organizations (Judd, Cooper, Fraser, & Davis, 2006; Kennedy, Maple, McKay, & Brumby, 2014), and these factors vary based on the type of agriculture pursued (Arnautovska, McPhedran, Kelly, Reddy, & De Leo, 2016).

Kurosu (1991) has pointed out that high suicide rates in rural areas may be influenced by recent dramatic changes in the sociopolitical trends related to farming (Kurosu, 1991). In many industrialized nations, including Japan, the economic and political conditions surrounding agriculture have changed dramatically since World War II. In Japan, where suicide has been considered a modern national phenomenon (Organization for Economic Co-operation and Development [OECD], 2017), the most dramatic changes in this area have happened in the field of animal husbandry since the 1960s. In that time, the supply of dairy products increased by three times, and beef, pork, and chicken supply increased by six to ten times or more (Food and Agriculture Organization [FAO], 2013). This was achieved through a powerful political initiative that positioned animal husbandry as a selective expansion sector under the Basic Law of Agriculture of 1961 and rapidly modernized the industry (Ministry of Agriculture, Forestry and Fisheries [MAFF], 2008). Modernization reduced the number of farmers while significantly increasing the quantity of livestock (MAFF, 2017a). This rapid modernization and structural change may have resulted in changing job demands and altering the stressors of farmers and farm-related workers (Lunner Kolstrup et al., 2013; Torske, Hilt, Glasscock, Lundqvist, & Krokstad, 2016). Since the 2000s, animal husbandry in Japan has faced additional issues in the form of challenging financial conditions and infectious disease epidemics due to globalization, including bovine spongiform encephalopathy, foot-and-mouth disease, and highly pathogenic avian influenza (Lunner Kolstrup et al., 2013; MAFF, 2017b). These challenges have resulted in significant job strain and mental stress placed on livestock and dairy farmers (Kondo & Oh, 2010; Van

Haaften, Olff, & Kersten, 2004). However, to our knowledge, no study has investigated the suicide risks of agricultural areas with a focus on the impact of the type of agriculture pursued.

With this in mind, the objectives of this study were twofold. First, we wished to test our hypothesis that the suicide rates in places where animal husbandry dominated would be higher than in areas where other agricultural forms dominate. Second, we aimed to observe potential temporal trends in the regional associations between animal husbandry and suicide for the longest possible period for which data were available.

METHOD

Data

To begin our study, we first made a visual observation of the nationwide regional distributions of agricultural activities and suicide in Japan using thematic maps of municipal data. We obtained age-standardized municipality-level suicide data provided by the Center for Suicide Prevention. Since the number of suicides was extremely small in some municipalities in certain years, the Center calculated the suicide rate by counting the number of suicides over the 5 years spanning from 2008 to 2012, divided by the sum of the local population for that period according to national vital statistics (Kubota et al., 2013). To determine the predominant type of agriculture practiced in each municipality, we obtained the "agricultural product sales price estimate" of 2010 from the Regional Economy Society Analyzing System (Cabinet Office, 2017). We also obtained government geospatial information and nationwide municipal boundary data from the Environmental Systems Research Institute Japan (ESRI, 2017b).

Next, we conducted regional association analysis, limiting our analysis to municipalities where agricultural land use was high. To do so, we evaluated the area characteristics using governmental statistics, namely the

Agricultural Area Type Classification (MAFF, 2017c), which is based on land use indicators, such as arable land, forestry land, residential land, and densely inhabited district. While constructing our points of analysis, we included agricultural municipalities only when all areas within a given municipality were agricultural areas (MAFF, 2010). Suicide data for different periods were obtained from the Center for Suicide Prevention as above. In this analysis, we used suicide data calculated every 5 years from 1983 to 2007. Since the agricultural data did not cover all the periods corresponding to the suicide data, we used different data sources from thematic maps. For the regression analysis, we obtained the yearly "agricultural output" from 1983 to 2005 from the Statistics of Agricultural Income Produced and used the 5-year average of agricultural output (MAFF, 2005). Since the agricultural data were limited to up to 2005, we only used the 3-year average in the last period. To obtain the data for covariates, we also used municipality summary statistics based on the population census conducted every 5 years.

Measurements

Suicide. Death certificate data include the cause of death, which is filled out by a physician and coded by trained coders according to the International Classification of Diseases, ICD-9 (9th revision, 1983–1994) and ICD-10 (10th revision, 1995–2012) (WHO, 1977, 1992). As suicide has different incidence rates by age and gender (Ministry of Health, Labour and Welfare [MHLW], 2017), we used male- and female-specific Standardized Mortality Ratios (SMR) of suicide for municipalities every 5 years using Bayesian estimation, as calculated by the Center for Suicide Prevention. In some small municipalities, suicide incidence was very low. Therefore, to minimize random errors attributed to population size, the Center provides the SMR smoothed using Bayesian estimation techniques, using the nationwide suicide count information to obtain prior distribution estimates and updating by observed

death counts information in the observation group. That is, in the following equation:

$$\frac{(\text{observed death counts} + \beta)}{(\text{expected death counts in the observed area} + \alpha)},$$

the Center assumed gamma distribution for prior distribution and estimated the α and β of each municipality from primary and secondary moments.

Predominant agriculture type(s). To measure the types of agriculture dominating each area, we used two proxy measures: agricultural product sales price estimate and agricultural output. The government calculates the agricultural product sales price estimate by multiplying the number of agricultural management bodies by the sales scales of the bodies by agricultural type (Cabinet Office, 2017). Annual agricultural output was calculated by multiplying production quantity and selling price for each type of agricultural product. To protect privacy, the government did not publish its data if there was only one management entity in a municipality. Thus, we interpreted the missing value as a minimum but not 0 and replaced with "1." During the observation periods, several municipalities were merged. To address these changes in our temporal trend evaluations, we adopted the latest municipality definitions, based on the municipality name and boundary data for 2013. Since the suicide data were available every 5 years, we calculated the 5-year average of the agricultural outputs to better evaluate the association between agricultural characteristics and suicide.

We aggregated the agricultural product sales price estimate and agricultural output by type of agriculture into "animal husbandry" and "agricultural crop." The animal husbandry category included dairy farming, beef cattle farming, pig farming, poultry farming, sericulture, and other livestock activities. The agricultural crop category included rice, wheat, potatoes, craft crops, vegetables grown outdoors, vegetables grown in greenhouses, fruits, flowers, and other agricultural crops. Next, we calculated the agricultural product sales price estimate and the agricultural output aggregated by these categories per unit population. Given the definitions of each proxy measure of agriculture, the values can represent the level of domination of each type of agriculture in the municipality's industry and the efficiency of the production means. We divided the values into four levels—"lowest," "low," "high," and "highest"—each accounting for 25 percentile points.

Covariates

In our regression analysis, we considered population density and the proportion of older adults in the population as potential confounders. This was suggested by a recent study indicating a negative correlation between suicide SMR and population density (Oka, Kubota, Tsubaki, & Yamauchi, 2015). The proportion of older adults in the population was determined as the number of people aged 65 years and above divided by the total population of the municipality. In recent years, population aging has been progressing more rapidly in rural and agricultural areas than urban areas, and because age is known to be a strong predictor of suicide (MAFF, 2015; MHLW, 2017), we determined that it was appropriate to control for this factor in particular.

Statistical analysis

To capture the general patterns of suicide and agriculture nationwide, we first observed the geographical patterns of suicide and agricultural activities using thematic maps. Then, to evaluate the statistical association between the types of agriculture and suicide over time, we conducted a multilevel linear regression analysis, taking into account a hierarchical structure of the time-series data. The level 1 variable was the period by 5-year intervals. The level 2 variable was the municipality. In the regression modeling, we evaluated overall municipal-level variations and associations between suicide SMR and each explanatory variable. Then, we created two multivariate models. The first model

included agricultural output, population density, and proportion of older residents (Model 1). Then, to address the impacts of systematic patterning of suicide and agricultural activities nationwide, in Model 2, we added region dummies representing 10 administrative regions in Japan: Hokkaido, Tohoku, Kanto and Higashiyama, Hokuriku, Tokai, Kinki, Chugoku, Shikoku, Kyushu, and Okinawa (Figure S1). We used Shikoku region as a reference because Shikoku showed the lowest regression coefficient of 10 regions. To evaluate potential temporal trends in the association between suicide SMR and agriculture types, we further added interaction terms of period dummies and agricultural output to the model and calculated predicted SMR trends by gender and agricultural type. We used Arc GIS 10.5 to create thematic maps and Stata 15.1 for all analyses (ESRI, 2017a; StataCorp, 2017).

Ethical approval

Since we exclusively used publicly available secondary aggrieved data in this study, formal ethical reviews were not required based on the guidelines of the Graduate School of Medicine and Faculty of Medicine at the University of Tokyo (The University of Tokyo, 2011). We obtained a formal confirmation of this from the Ethics Review Board of the Graduate School of Medicine and Faculty of Medicine at the University of Tokyo (11887).

RESULTS

From the thematic maps of the entire country, we observed that both suicide SMR and agricultural product sales are unevenly localized. Both suicide SMR and animal husbandry product sales amount estimates per unit population seemed high in the eastern parts of Hokkaido, Tohoku, and Chugoku, as well as the southern parts of Kyushu (Figures S1 and S2).

Of the 1,742 total municipalities nationwide, 404 met our inclusion criteria,

indicating a high rate of agricultural land use (Figure 1). Many agricultural areas are located in the Hokkaido and Kyushu regions. Population density was low for both municipalities with the highest animal husbandry output per unit population and highest agricultural crops (Table 1). Descriptive data showed that suicide SMRs are proportionately high among the municipalities where the animal husbandry output per unit population is high, whereas no such trend was clear for agricultural crops per unit population (Table 2). The null model of regression analysis showed that the SMRs varied significantly across agriculture-dominated municipalities: coefficients (standard errors) were 161.23 (14.76) in men and 98.95 (10.43) in women. Nonadjusted univariate models showed that the animal husbandry output per unit population was positively associated with suicide SMR in both genders: Compared to areas with the lowest output quartile, the SMRs in the areas with the highest output quartile were larger by 5.63 points in men (95% confidence intervals: 2.17–9.08) and 8.46 in women (95% confidence intervals: 5.48–11.43). However, these associations were less clear for agricultural crop output. These associations were similarly observed in multivariate models, with slight changes in SMR estimates (Tables 3 and 4).

For variables other than agriculture shown in Tables 3 and 4, suicide SMR was significantly lower when the proportion of older people was higher in both males and females. In Model 2, male suicide SMR was significantly higher in Tohoku, Kyushu, and Okinawa than in Shikoku. Women's suicide SMR in almost all areas was higher than in Shikoku.

With regard to temporal trends, the suicide SMR patterning by agriculture type did not change significantly over time: The data demonstrated a continuously high suicide SMR in the municipalities with the highest animal husbandry output per unit population (Figure 2). The difference in SMR by level of animal husbandry output per unit population has gradually expanded and has become remarkable since 1993. The male suicide SMR was significantly lower in 1998–
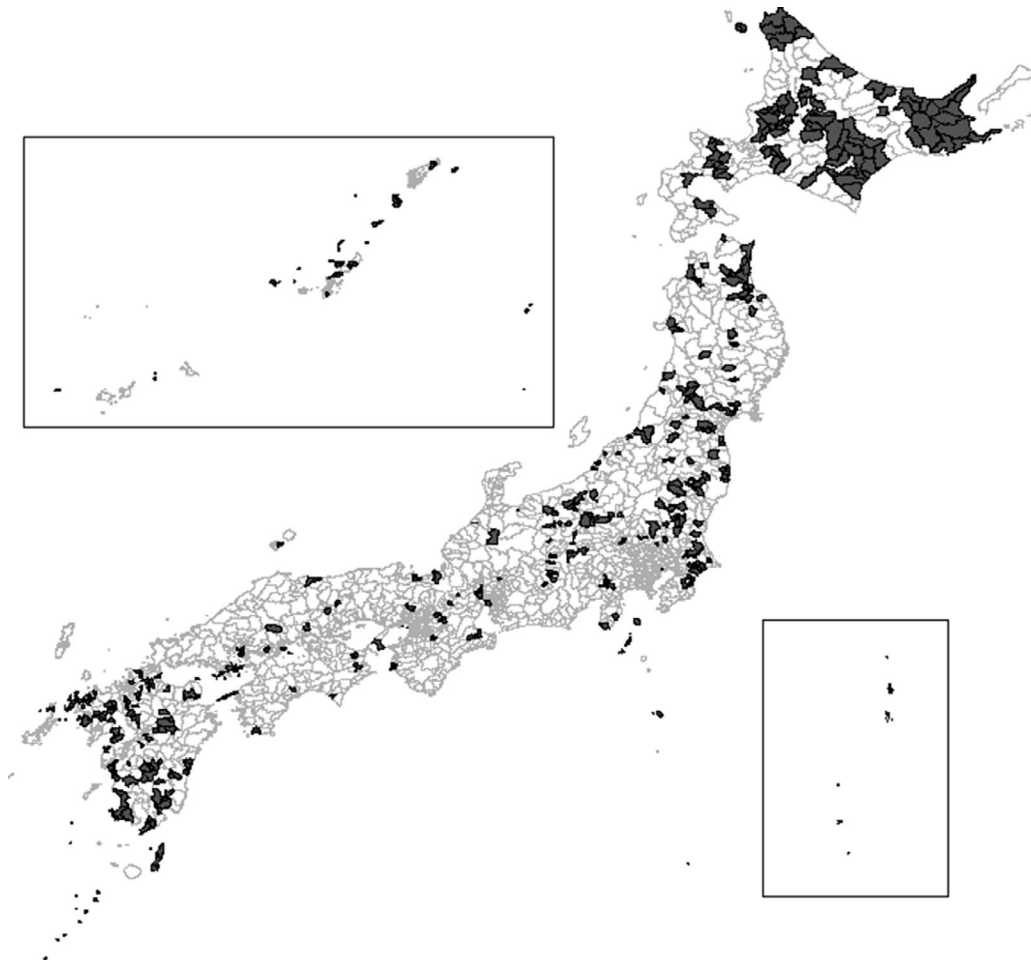
Figure 1. Agriculture-dominated municipalities throughout Japan selected for regression analysis.

2002 compared to other periods between 1983 and 2003. Male suicide SMR has been rapidly increasing, with a particular growth seen in the period from 2003 to 2007 in municipalities with a "high" (i.e., the second highest) level of animal husbandry output. No such correlations could be observed in the data relating to agricultural crop per unit population.

DISCUSSION

This time-series regional association study indicates that municipalities with a high animal husbandry output show high suicide mortality in both genders, with a stronger relationship among females than males, whereas there is no observable association between crop production and suicide. Temporal analysis shows that the association could be observed consistently throughout the period between 1983 and 2007. These results support our hypothesis that the suicide rates of the places where animal husbandry dominates would be higher than the areas where other agriculture dominates. Moreover, the trend displayed some specific features, including the potential relative increases in female SMR among the municipalities with the highest animal husbandry outputs and decreases in male suicide SMR regardless of agriculture types, specifically between 1998 and 2002.

TABLE 1
Characteristics of Municipalities by Type of Agriculture

	Agricultural crop output per unit population				Animal husbandry output per unit population			
	Lowest	Low	High	Highest	Lowest	Low	High	Highest
Number	502	503	503	503	502	503	503	503
Population density	5.11 (3.84)	4.09 (1.65)	3.36 (1.68)	1.64 (1.24)	5.35 (3.39)	3.79 (2.28)	3.28 (1.68)	1.78 (1.49)
Proportion of older people	20.11 (6.94)	20.77 (6.11)	20.38 (5.69)	20.24 (5.99)	21.11 (6.47)	20.31 (5.86)	19.75 (6.2)	20.32 (6.2)

Note. Animal husbandry and agricultural output per unit population were divided into four levels of 25 percentile points (i.e., "lowest," "low," "high," and "highest"). Mean (SD).

This study demonstrates the existence of potential farming-related risks on individual mental stresses. Work-related risks among animal husbandry workers include long working hours, lack of off-season, physical hazards that cause injury, animal diseases, intense job demand, social isolation, increasing economic pressure due to recent structural changes related to modernization, and the exposure to the death of livestock animals (Lunner Kolstrup et al., 2013; Torske et al., 2016; Van Haaften et al., 2004; Watanabe, Hukuchi, Kanamori, & Nishiyama, 1983). In addition, external stressors, such as governmental policies and social responsibility for animal welfare, food quality, and food security, have led farmers to perceive an increasingly heavy burden (Kallioniemi, Simola, Kaseva, & Kymäläinen, 2016).

Our study suggests that female animal husbandry workers experience greater mental stress than their male counterparts. Although approximately half of Japan's agricultural workers are female, <10% of the leaders in agricultural organizations are female (MAFF, 2018). In other words, women tend to have less power in managing their jobs. Abundant evidence suggests that high job demands and low decision latitude predict high mental burden (Karasek, 1979). Wendt and Hornosty (2010) have reported that women in rural areas often prioritize their families and either conceal or disregard their own health concerns, including family violence (Wendt & Hornosty, 2010). Gender norms may also explain our findings of high male suicide rates in areas dominated economically by animal husbandry. Studies suggest that the sense of masculinity is a risk factor for male suicide and mental disorders in rural areas, potentially causing male farmers to avoid seeking help for fear of being perceived as weak or unmasculine. (Alston, 2012; Laoire, 2001; Roy, Tremblay, Oliffe, Jbilou, & Robertson, 2013). Male-centered social structures are common in Japanese rural areas, too (MAFF, 2018). Hence, the gender gap we observed in this study may reflect both occupational and social burdens among female and male animal husbandry workers.

TABLE 2
Suicide SMR by Municipality Characteristics

	Suicide SMR	
	Male	Female
Animal husbandry output per unit population		
Lowest [0–2.31]	107.39 (19.57)	100.01 (15.84)
Low [2.32–6.71]	108.77 (17.39)	101.89 (17.43)
High [6.73–16.47]	111.3 (20.25)	104.63 (17.8)
Highest [16.51–270.39]	113.55 (21.76)	108.41 (20.75)
Agricultural crop output per unit population		
Lowest [0–10.67]	107.32 (17.74)	101.29 (15.41)
Low [10.73–21.2]	110.87 (20.8)	104.14 (19.56)
High [21.21–34.71]	112.29 (21.03)	105.34 (20.66)
Highest [34.71–555.54]	110.54 (19.72)	104.18 (16.91)
Population density		
Lowest [0.2–1.65]	108.02 (16.99)	102.95 (14.3)
Low [1.65–3.17]	114.9 (22.87)	107.75 (21.74)
High [3.17–4.75]	110.3 (19.14)	104.18 (19.05)
Highest [4.76–20.75]	107.8 (19.51)	100.07 (16.46)
Total	110.25 (19.93)	103.74 (18.3)

Animal husbandry and agricultural output per unit population were divided into four levels of 25 percentile points (i.e., "lowest," "low," "high," and "highest"). Proportion of older people: mean = 20.37, SD = 6.20.
Mean (*SD*)

It is worth noting that the high suicide rate found in animal husbandry areas does not mean that these suicides were only committed by farmers; the suicide rate also includes all other residents in those areas, including farmers' families and those engaged in other occupations. In Japan, there are 2.6 million farmers (2% of the total population), of which animal husbandry workers are estimated to only comprise several hundred thousand as of 2010 (MAFF, 2010). Even if all the animal husbandry workers in Japan lived in the municipalities we analyzed, this would still represent <10% of the total population of 5.4 million included in the analyzed areas. We could speculate that the contextual effect related to suicide and animal husbandry exists. Previous studies in social psychology have suggested that the characteristics between farming and herding communities differ, affecting not only farmers but also other residents (Uchida et al., 2018; Uskul & Over, 2014). Thus, there is a need for additional research into the potential place effects in play, which are the classical province of epidemiology and health sociology (Durkheim, 1897).

The exposure to the death of livestock animals might explain the results. According to the interpersonal theory of suicide by Joiner, repeated exposure to physically painful and/or fear-inducing might appear in habituation and a sense of fearlessness to the death and produce capability for suicide, possibly causing suicidal behavior (Chu et al., 2017; Joiner, 2005; Van Orden et al., 2010). The exposure to the death seems rather common in communities where animal husbandry has thrived, where, structurally, many people experience animal deaths on a daily basis, such as farmers, farmers' families, agricultural laborers, veterinarians, slaughterers, and disposal workers for sick animals. The experience related to death, such as euthanasia, might have a severe impact on suicide (Klingelschmidt et al., 2016; Van Haaften et al., 2004; Witte, Correia, & Angarano, 2013).

TABLE 3

Regression Coefficient (95% Confidence Intervals) for Male Suicide SMR: Results of Multilevel Linear Regression Analysis

		Male		
			Multivariate	
	Null	Univariate	Model 1	Model 2
Constant[a]	110.24 (0.72)		101.27 (3.96)	89.59 (6.17)
Animal husbandry output per unit population				
Lowest		Reference	Reference	Reference
Low		1.23 (−1.57 to 4.02)	1.18 (−1.7 to 4.06)	0.52 (−2.31 to 3.34)
High		2.38 (−0.75 to 5.51)	2.34 (−1.02 to 5.69)	1.15 (−2.1 to 4.41)
Highest		5.63 (2.17 to 9.08)	6.16 (2.34 to 9.99)	4.89 (1.21 to 8.57)
Agricultural crop output per unit population				
Lowest		Reference	Reference	Reference
Low		3.26 (0.2 to 6.32)	2.46 (−0.69 to 5.6)	2.41 (−0.65 to 5.47)
High		3.63 (0.36 to 6.9)	2.66 (−0.83 to 6.15)	2.24 (−1.12 to 5.6)
Highest		2.33 (−1.23 to 5.89)	2.2 (−1.71 to 6.11)	2.17 (−1.55 to 5.88)
Period				
2003–2007		Reference	Reference	Reference
1998–2002		−5.13 (−7.24 to −3.03)	−4.27 (−6.51 to −2.02)	−4.09 (−6.34 to −1.83)
1993–1997		−3.45 (−5.55 to −1.34)	−1.54 (−4.28 to 1.2)	−1.14 (−3.92 to 1.63)
1988–1992		−2.51 (−4.61 to −0.41)	0.29 (−3.18 to 3.75)	1 (−2.54 to 4.53)
1983–1987		−3.86 (−5.97 to −1.75)	−0.16 (−4.28 to 3.97)	0.78 (−3.45 to 5.01)
Population density				
Highest		Reference	Reference	Reference
High		0.93 (−2.29 to 4.15)	−1.35 (−4.73 to 2.03)	−2.07 (−5.41 to 1.27)
Low		4.25 (0.79 to 7.71)	0.61 (−3.23 to 4.46)	−0.72 (−4.64 to 3.2)
Lowest		0.57 (−3.09 to 4.23)	−3.41 (−7.82 to 1.01)	−1.44 (−6.82 to 3.94)
Proportion of older people (per % unit change)				
		0.21 (0.07 to 0.34)	0.34 (0.05 to 0.62)	0.39 (0.1 to 0.69)
Area				
Hokkaido		5.75 (−2.86 to 14.36)		7.21 (−2.25 to 16.68)
Tohoku		16.9 (8.15 to 25.65)		19.17 (10.24 to 28.11)
Kanto and Higashiyama		6.08 (−2.77 to 14.93)		8.54 (−0.39 to 17.46)
Hokuriku		0.34 (−9.39 to 10.07)		2.59 (−7.09 to 12.27)
Tokai		−3.27 (−14.14 to 7.61)		0.85 (−10.11 to 11.8)
Kinki		2.93 (−8.14 to 14.01)		6.44 (−4.66 to 17.54)
Chugoku		7.94 (−3.35 to 19.24)		7.64 (−3.62 to 18.91)
Shikoku		Reference		Reference
Kyushu		14.63 (6.04 to 23.23)		15.82 (7.28 to 24.36)
Okinawa		10.35 (0.15 to 20.54)		12.08 (1.8 to 22.35)
Random parameters				
Between-municipalities variance[a]				
	161.23 (14.76)		149.36 (14.08)	122.29 (12.08)

[a]*SE* in parentheses.

TABLE 4

Regression Coefficient (95% Confidence Intervals) for Female Suicide SMR: Results of Multilevel Linear Regression Analysis

|		Female		
			Multivariate	
	Null	Univariate	Model 1	Model 2
Constant[a]	103.72 (0.60)		98.35 (3.47)	81.21 (5.36)
Animal husbandry output per unit population				
Lowest		Reference	Reference	Reference
Low		1.89 (−0.69 to 4.46)	1.68 (−0.98 to 4.34)	1.95 (−0.67 to 4.57)
High		4.28 (1.49 to 7.07)	4.15 (1.16 to 7.14)	4.64 (1.71 to 7.57)
Highest		8.46 (5.48 to 11.43)	8.86 (5.53 to 12.19)	9.89 (6.64 to 13.14)
Agricultural crop output per unit population				
Lowest		Reference	Reference	Reference
Low		2.02 (−0.75 to 4.8)	0.29 (−2.55 to 3.14)	−0.37 (−3.15 to 2.41)
High		3.52 (0.6 to 6.44)	0.99 (−2.09 to 4.07)	0.32 (−2.67 to 3.31)
Highest		2.64 (−0.45 to 5.74)	0.99 (−2.38 to 4.36)	0.79 (−2.45 to 4.04)
Period				
2003–2007		Reference	Reference	Reference
1998–2002		−1.18 (−3.3 to 0.94)	−1.05 (−3.28 to 1.17)	−0.29 (−2.52 to 1.94)
1993–1997		−0.28 (−2.4 to 1.84)	−0.05 (−2.66 to 2.56)	1.57 (−1.09 to 4.22)
1988–1992		−0.85 (−2.97 to 1.26)	−0.92 (−4.11 to 2.28)	1.61 (−1.68 to 4.9)
1983–1987		−2.12 (−4.24 to 0)	−2.06 (−5.8 to 1.68)	1.21 (−2.67 to 5.09)
Population density				
Highest		Reference	Reference	Reference
High		3.94 (1.08 to 6.8)	2.11 (−0.88 to 5.11)	0.6 (−2.39 to 3.59)
Low		6.48 (3.47 to 9.49)	3.45 (0.09 to 6.8)	1.76 (−1.7 to 5.22)
Lowest		3.09 (−0.03 to 6.2)	−1.65 (−5.46 to 2.16)	−1.09 (−5.83 to 3.66)
Proportion of older people (per % unit change)				
		0.14 (0.01 to 0.27)	0.05 (−0.2 to 0.3)	0.31 (0.04 to 0.57)
Area				
Hokkaido		8.49 (1.01 to 15.97)		8.5 (0.52 to 16.48)
Tohoku		16.16 (8.56 to 23.76)		16.84 (9.34 to 24.34)
Kanto and Higashiyama		12.65 (4.97 to 20.34)		14.45 (6.96 to 21.93)
Hokuriku		11.38 (2.93 to 19.83)		13.62 (5.52 to 21.72)
Tokai		7.95 (−1.49 to 17.39)		12.36 (3.17 to 21.54)
Kinki		10.01 (0.40 to 19.63)		14.61 (5.31 to 23.91)
Chugoku		5.13 (−4.68 to 14.94)		4.23 (−5.2 to 13.66)
Shikoku		Reference		Reference
Kyushu		8.18 (0.72 to 15.65)		8.48 (1.34 to 15.63)
Okinawa		2.29 (−6.56 to 11.15)		2.88 (−5.73 to 11.5)
Random parameters				
Between-municipalities variance[a]	98.95 (10.43)		84.29 (9.51)	70.90 (8.50)

[a]*SE* in parentheses.
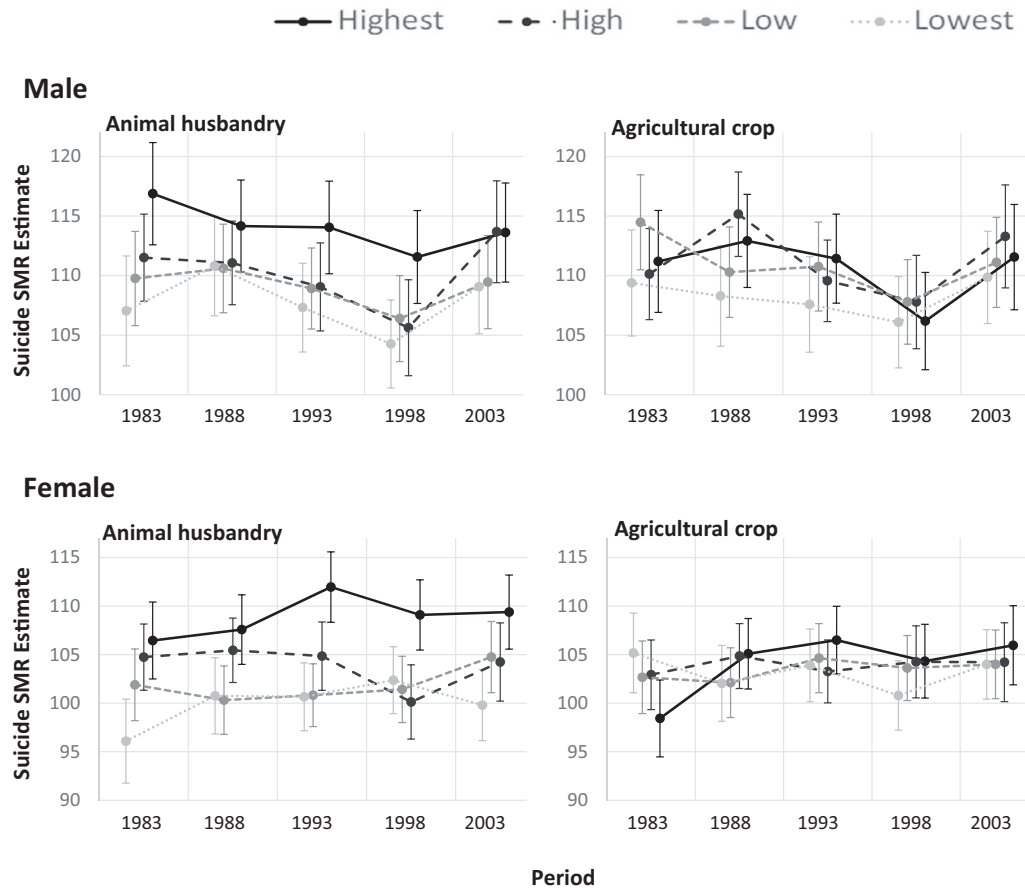
Figure 2.   Trends in suicide SMRs by the levels of agricultural production output by agriculture type in men and women among 404 agriculture-dominated municipalities in Japan, 1983–2007. Models were adjusted for population density and proportion of older people.

A sense of discrimination and internal stigma experienced by animal husbandry workers/communities might also explain their increased suicide risk. In Japan, workers who may end an animal's life as part of their animal husbandry duties have historically been discriminated against, as it is thought that they are *kegare* "defiled" according to both the indigenous Japanese Shinto religion and Buddhism (Reber, 1999). Indeed, until about 100 years ago, a caste system set apart many rural individuals into the lowest social group of *burakumin*; slaughterhouse and butchery workers were among those ostracized for their perceived "defilement" by death. Community-level discrimination still

exists across Japan, as demonstrated by calling the areas, where former *etta* and other discriminated people reside, "buraku" (Sunda & Milner, 2015; Tomonaga, 2007). Recent surveys have revealed a strong link between perceived discrimination and mental risks in these areas (Tabuchi, Fukuhara, & Iso, 2012).

Although the strong effects of macrosocial contexts and their effects on suicide have been repeatedly suggested in the literature, our findings showed stable temporal trends, even given the major economic crisis in the 1990s and several epidemics of animal infectious diseases. Although we found a relative reduction in suicide SMR among male residents in farming areas since 1998, this

may mirror the increase in suicide in urban areas after the Asian financial crisis in 1998; evidence indicates an increase in suicides among managers and professionals in that time (Wada et al., 2012). Overall, our data indicate that the effects of community and social contexts on the patterning of suicide rates in rural areas in Japan have been stable over the past 25 years, except for the municipalities with the highest animal husbandry outputs, where female suicide increased. This might be due to the dramatic changes in the animal husbandry industry in Japan: Increasing farm size could make the community sparse and decrease social interactions among residents, while increasing economic pressures, such as those attributable to international competition in the meat and dairy industries, may also play a role.

Limitations

This study has the following limitations. First, our regional association analysis could not distinguish between compositional and contextual effects. If the compositional effects (i.e., the effects of job-related stresses and stigma experienced by livestock farmers) are the primary reasons for the trends observed, the most effective suicide prevention measures may be based on industrial health perspectives, such as improving individuals' work environment, economic burden, and job-related social relationships. However, if the contextual effects are more influential, it might be better to consider more political, macroindustrial, and community organizational factors when constructing suicide prevention policies. Nonetheless, given that the purpose of this study was to generate hypotheses worthy of further study, we consider our study design appropriate. Second, due to constraints of data availability, we used the municipality as the basic unit of analysis, but this unit may not be fully appropriate. Specifically, we had to omit the data of

municipalities that included farming areas within a larger scope than the analysis. This could occur among large cities that include both urban and rural areas in their official boundaries. Even in the municipalities that we did analyze, some small areas may contain urban characteristics. Hence, selective bias may have occurred due to these unit problems.

CONCLUSION

Despite the limitations discussed, this study revealed the high risk of suicide in Japanese municipalities where animal husbandry is the major defining industry. Potential gender-specific temporal trends in the association between animal husbandry and suicide also warrant further study. Future studies should use relevant data at both the individual and community levels and accordingly evaluate both the individual behavioral risks of farmers and more contextual factors at the community, national, and global levels. Identifying the contributing contextual factors is particularly important, as these could be targeted by public health interventions to prevent suicide and create healthy farming communities. For example, as discussed in this paper, potential factors of interest include the community cultural characteristics (e.g., masculinity, historical systematic discrimination, and related internal stigma) and the work environment related to animal husbandry. Moreover, this study suggests the importance of evaluating the health effects of relevant national and global policies on agricultural communities, including price control policies for agricultural products, labor standard reforms, national economic policies, and international trade agreements involving agricultural products (Schrecker, Labonté, & De Vogli, 2008; Smith, Blouin, Mirza, Beyer, & Drager, 2015).

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SUPPORTING INFORMATION

Additional Supporting Information may be found in the online version of this article:

Figure S1. Japan's 10 administrative regions: Hokkaido, Tohoku, Kanto and Higashiyama, Hokuriku, Tokai, Kinki, Chugoku, Shikoku, Kyushu, and Okinawa. Source: Agriculture and forestry census by the Ministry of Agriculture, Forestry and Fisheries.

Figure S2. Thematic maps of the entire country of Japan divided by municipality unit.