Jikeikai Med J 2010 ; 57 : 101-11

Ecological Study : Land Cloud Cover and Suicide in Japan

Tomoe SHIMADA and Mitsuyoshi URASHIMA

Division of Molecular Epidemiology, The Jikei University School of Medicine

ABSTRACT

Objective : To clarify whether socioeconomic or climate factors are associated with suicide.

Methods : Suicide rates, age-adjusted suicide rates, climate factors, including land cloud cover, and economic factors, including unemployment rates, were retrieved from publications by governments or national centers and analyzed with multiple linear regression models.

Results : In the annual national model, land cloud cover, the unemployment rate, and the suicide rate/age-adjusted suicide rate all increased in 1998. When the study period was restricted to after 1997, both land cloud cover and unemployment were independently and positively associated with the male age-adjusted suicide rate ($R^2=0.89$). In the monthly national model, land cloud cover and sun exposure time, rather than sunshine, were strongly associated with age-adjusted suicide rates, even after multivariate adjustment for socioeconomic factors ($R^2=0.76$). In the annual prefectural model, the addition of land cloud cover rather than sunshine and sun exposure time to a variety of socioeconomic factors significantly improved the accuracy of the model (likelihood ratio test, $P<0.0001$).

Conclusions : These results suggest that in addition to higher unemployment rates and other socioeconomic indices, more land cloud cover may increase age-adjusted suicide rates in both males and females. (Jikeikai Med J 2010 ; 57 : 101-11)

Key words : suicide, land cloud cover, sun exposure, climate, unemployment

INTRODUCTION

Suicide is the act of deliberately killing oneself[1]. Risk factors for suicide include mental disorders, such as depression, personality disorders, alcohol dependence, and schizophrenia, and some physical illnesses, such as neurological disorders, cancer, and human immunodeficiency virus infection[1]. According to the World Health Organization, in 2000 approximately 1 million people committed suicide worldwide, and 10 to 20 times as many people attempted suicide[2]. Thus, suicide is an important global social problem.

Compared with those in 1997, male suicide rates in 1998 increased by 39% in Japan, 44% in Hong Kong, and 45% in Korea ; these increases were thought to be related to the economic crisis and increased unemployment rates[3]. Suicides in Japan have numbered around 30,000 per year (25 per 100,000 population) since 1998 and accounted for 2.8% of all deaths in 2007[4]. Studies in Japan[5], the United States[6], England[7], and other developed counties[8,9] have suggested a strong correlation between unemployment and suicide. Moreover, being from a low-income family is also a risk factor for suicide[10]. Although about half of this association might be attributable to a confounding mental illness[11,12], this correlation is not always true in all countries[13,14]. The latest economic crisis occurred in 2008 and is ongoing, but we do not yet know how it has affected suicide rates.

The clear seasonality of suicide is empirically

Received for publication, December 10, 2009

島田　智恵，浦島　充佳

Mailing address : Mitsuyoshi URASHIMA, Division of Molecular Epidemiology, The Jikei University School of Medicine, 3-25-8, Nishi-Shimbashi, Minato-ku, Tokyo 105-8461, Japan.

E-mail : urashima@jikei.ac.jp

well known; for example, suicide rates are higher from late spring to early summer, which seems to be a worldwide phenomenon[15]. This seasonal variation is more evident in suicide victims with a psychiatric inpatient diagnosis than in those without such a diagnosis[16]. Although evidence regarding the effect of weather and climate on suicide is not consistent[17], seasonality tends to be more significantly associated with suicide at higher latitudes[18,19] and less significantly associated with suicide at lower latitudes, such as in Brazil and Singapore[20,21]. Among the climatic factors, lack of exposure to sunshine may trigger suicide[22,23]. Moreover, global warming has been suggested to increase deaths due to suicide[24], independent of the economic situation.

Solar radiation reaching the land is strongly affected by land cloud cover through the reflection and absorption of sunlight[25]. Global warming facilitates the hydrologic cycle and increases cloud cover[26,27]. In addition, anthropogenic aerosols, driven by industrialization and an expanding population, can also increase cloud cover. In particular, the land cloud cover in Japan is strongly influenced by aerosols from industrialized parts of China[28]. Together, slow economic growth, high unemployment rates, and recent changes in land cloud cover or sunshine/sun exposure time may affect suicide rates in Japan. However, previous reports have only analyzed the effects on suicide of economic factors or climatic factors separately. Therefore, in the present study we aimed to clarify the effects of land cloud cover on suicide rates by adjusting for economic variables using multiple regression models and likelihood ratio tests.

Methods

Suicide deaths as an outcome measure

Three models—an annual national model, a monthly national model, and an annual prefectural model—were made to assess the effects of climate on suicide rates. For the annual national model, the annual number of suicides, rates of suicide/100,000 population, and age-adjusted suicide rates from 1950 through 2007 were obtained from the homepages of the Japan Suicide Prevention Centre summarized by Professor Toshiharu Fujita[29]. Teh age-adjusted suicide mortality rate in Japan was calculated with the following formula: S[(suicide mortality rate of age group in a certain year, Japan)×(population of the age group in 1985, Japan)]/(total population in 1985, Japan). For the monthly national model, monthly suicide numbers and rates in Japan were abstracted from the vital statistics of Japan from 1961 through 2006[16]. For the annual prefectural model, annual age-adjusted suicide mortality rates/100,000 population in each prefecture from 1980 through 2006 were cited from the home pages of the Japan Suicide Prevention Centre[30]. The age-adjusted suicide mortality rate in each prefecture was calculated with the following formula: S[(suicide mortality rate of age group in a prefecture in a given year)×(population of the age group in 1985, Japan)]/(total population of Japan in 1985). Because of the limitation of data resources, each of the 3 models in this study analyzed data for different periods and included different variables.

Climate variables as exposure measures

Monthly and annual average land cloud cover, sun exposure time, and sunshine in the capitals of the 47 prefectures (1961–2006) were based on data published by the Japan Meteorological Agency[31]. An observer scored the ratio of land cloud cover in the sky from 0 to 10 at 3 a.m., 6 a.m., 9 a.m., 12 p.m., 3 p.m., 6 p.m., and 9 p.m. every day. A score of 0–1 indicated a clear sky; 2–8 a partly cloudy sky, and 9–10 a cloudy sky. Sun exposure time (hours) was counted when sun exposure was more than 120 W/m^2 measured with a specified device. Sunshine (%) was calculated as sun exposure time divided by time from sunrise to sunset. When land cloud cover data were used for the monthly national model, data were weighted by the population of each prefecture as follows: population-weighted land cloud cover = sum of 47 prefectures [(monthly land cloud cover in a prefecture in a given year)×(population of the prefecture in the year)/total population in the year], assuming populations were the same during the year. Because we do not know if the effects of land cloud cover are short term or long term, land cloud cover for 1 month to a total of 20 months before the month for suicide death rates was calculated as 20 different variables. For the annual and national models (Fig. 1), these monthly data were averaged. When the land cloud cover data were used for the annual prefectural model, annual mean data observed in the prefectural capital were used directly. Similarly, mean sunshine (%) and sun exposure time (hours) were weighted by populations for the monthly national model. They were also used directly for the annual prefectural model.

Economic variables as exposure measures

Economic variables (1980–2006) included gross national product, prefectural income, working population, employment population, income per employee, per capita income, and the percent gain and loss of each variable compared with the previous year. All data were taken from the homepage of the Cabinet Office, Government of Japan[32]. During the study, per capita income was highest in Tokyo. Thus, the "difference in per capita income from the maximum prefecture's" was calculated in each year as follows : [per capita income of Tokyo] − [per capita income of each prefecture].

Statistical analysis

The annual national model, monthly national model, and annual prefectural model were designed to examine the effects of climate on suicide rates in different ways. We used the software program Stata version 9.1 for statistical analysis (StataCorp LP, College Station, TX, USA). Before linear regression analyses, issues of skewness, collinearly, and outliners were examined. First, single linear regression models were applied to identify significant associations between outcomes and exposures. Next, using significant variables identified with the single linear regression models, multiple linear regression models and their R^2 values were computed to determine which factors independently affected suicide deaths in the monthly national model and the annual prefectural model. We used the likelihood ratio test to determine whether the addition of land cloud cover significantly improved the ability of the model to predict suicide rates on the basis of socioeconomic factors. A P-value <0.05 was considered to indicate significance.

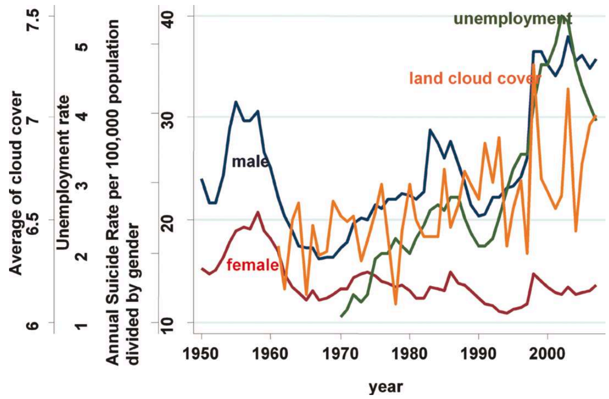
Results

Annual national model of suicide

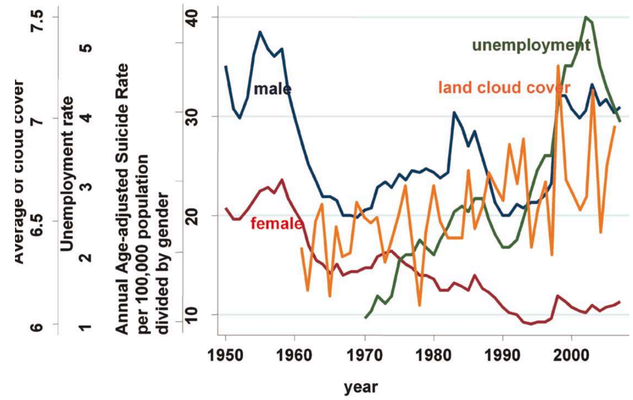
The annual suicide rate per 100,000 population and the annual age-adjusted suicide rate per 100,000 population overlaid with unemployment rates and land cloud cover are shown in Fig. 1A and 1B, respectively. The suicide rate of males increased after late 1960, was approximately 36 per 100,000 after 1998, and reached 38 per 100,000 in 2003. There were 3 prominent peaks in the male epidemic curve : 1950, 1980, and after 1998. In contrast, rates in females were relatively stable, especially after 1960. When the suicide rate was adjusted by age, the increasing trend in males disappeared and the relatively stable curve in females showed a decreasing trend. The suicide rate of males was always higher than that of females during the study period. In 1969, males committed suicide 1.38 times more often than did females. Over time, the differences became greater, and in 2003 males committed suicide 3.05 times more often than females.

Land cloud cover, unemployment rate, and suicide rate/age-adjusted suicide rate all increased to high levels in 1998. When the study period was limited to after 1997, both land cloud cover and the unemployment rate were independently associated with the male age-adjusted suicide rate in the multiple linear regression model ($R^2=0.89$, $R=0.95$) (Fig. 1C). The addition of land cloud cover to unemployment significantly increased the accuracy of the model to predict age-adjusted suicide rates (likelihood ratio test : $P=0.0013$).

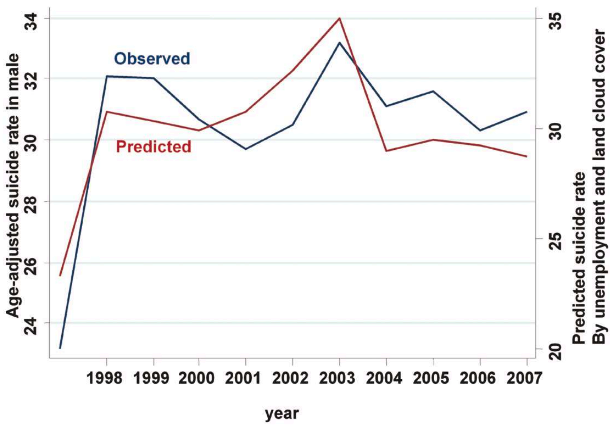
Using data from 1950 to 2007, associations between unemployment rates and suicide rates as well as age-adjusted suicide rates divided by gender are shown in Fig. 2A and 2B, respectively. In males, the unemployment rate was positively and significantly associated with the suicide rate ($R=0.94$, $R^2=0.88$, $P<0.001$). In contrast, no significant association was seen in females. When the suicide rate was adjusted by age, the degree of association in males was



A



B



C

Fig. 1. Trends in suicide rates from 1950 through 2007
A : Annual suicide rates per 100,000 population. B : Annual age-adjusted suicide rates per 100,000 population. All suicides rate are overlaid with unemployment rates (%) and mean land cloud cover. C : Observed age-adjusted suicide rates of males and predicted rates by cloud cover and unemployment rates are shown from 1997 through 2007. Predicted rate=5.178929*(cloud cover)+3.9528*(unemployment rate)−23.03236.

reduced. Interestingly, the female age-adjusted suicide rate was negatively associated with the unemployment rate ($R=-0.65$, $R^2=0.42$, $P<0.001$).

Monthly national model of suicide

Because the correlations were strong between land cloud cover and sunshine ($g=-0.9$) and between sunshine and sun exposure time ($g=1.0$), sunshine was not used in multivariate analysis. In the multivariate analysis using land cloud cover and sun exposure time, land cloud cover, but not sun exposure time, was significantly associated with the suicide rate ($P<0.001$). Thus, we used land cloud cover in the following analyses.

To investigate the effect of land cloud cover on the seasonality of suicide, multivariate analysis was performed with land cloud cover and the months from January through December (Table 1). Land cloud cover values from March through June compared with August showed positive associations with suicide rates. The addition of land cloud cover to months significantly improved the model's accuracy to predict age-adjusted suicide rate (likelihood ratio test : $P<0.0001$).

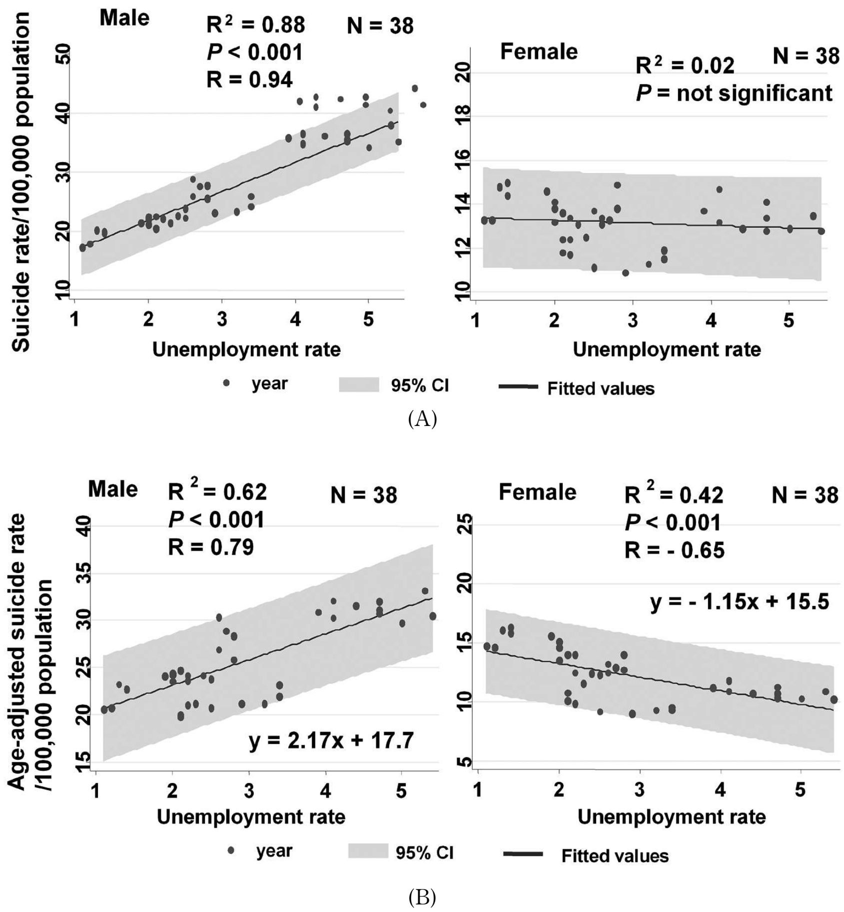


Fig. 2. Associations between unemployment and suicide rates from 1970–2007, divided by gender
From 1970 through 2007, 38 points were plotted based on annual unemployment rates (%), suicide rates (/100,000) (A), and age-adjusted suicide rates (/100,000) (B) of the year divided by gender. The predicted line and its 95% confidence intervals are also shown.

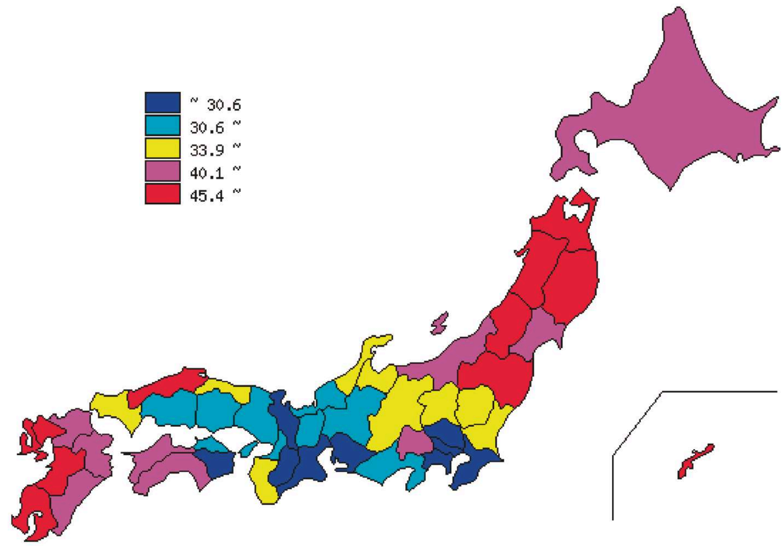
Table 1. Multiple linear regression model to predict national monthly suicide rates (1970–2006)*

	Coefficient	*T*	*P* value
Land cloud cover	0.078	4.14	<0.001
January	0.123	1.76	0.08
February	0.033	0.50	0.62
March	0.312	4.98	<0.001
April	0.323	5.32	<0.001
May	0.327	5.51	<0.001
June	0.166	2.89	0.004
July	0.055	0.97	0.33
August	0	–	–
September	0.052	0.90	0.37
October	0.062	1.09	0.28
November	0.062	1.00	0.32
December	0.037	0.57	0.57

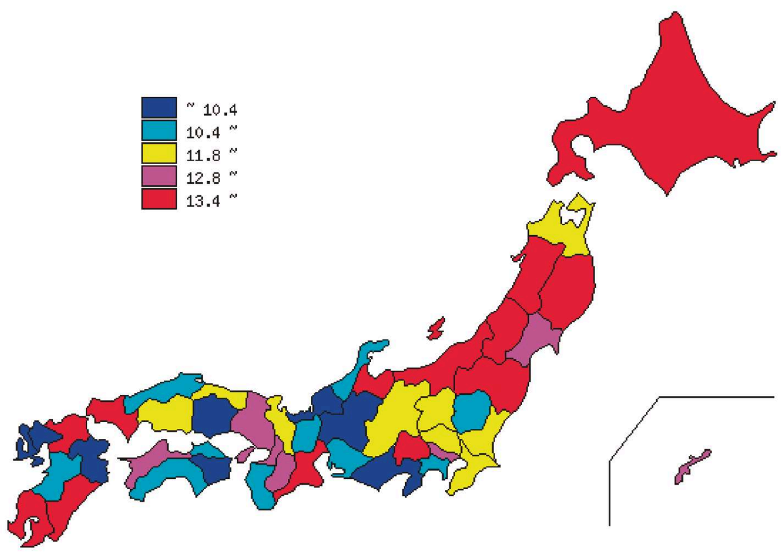
Annual prefectural model of suicide

Age-adjusted suicide rates in each prefecture in 2006 are shown in Fig. 3A for males and Fig. 3B for females. Male age-adjusted suicide rates ranged from 23.8 (Nara Prefecture) to 64.4 (Akita Prefecture), representing a difference of a factor of 2.7 between prefectures. Female age-adjusted suicide rates ranged from 9.0 (Okayama Prefecture) to 17.1 (Ooita Prefecture), representing a difference of a factor of 1.9 between prefectures.

Climate differs among prefectures, and even within a single prefecture the climate can vary year to year. Therefore, we created the annual prefectural model of suicide to examine the association of age-adjusted suicide rates for each prefecture, the annual averages of land cloud cover, and economical vari-



(A)



(B)

Fig. 3. Age-adjusted suicide rates in each prefecture in 2006
A : males, B : females. Suicide rates were simply quintupled.

ables, including the unemployment rate, for each prefecture using the same year. Analyses with single and multiple linear regression models were then performed (Tables 2A and 2B). When we used the single linear regression model, all variables listed in Table 2A showed significant associations with male annual suicide rates in the prefecture. However, among the variables used in the single linear regression models, the variables strongly ($P<0.001$) associated with suicide rate were land cloud cover, the increase/decrease in population density, income per employee, the gain/loss of income per employee, per capita income, the difference in per capita income from the max prefecture's, and the unemployment rate. This finding was considered to explain the 69% variance in suicide rates observed among prefectures ($R^2=0.69$). The addition of land cloud cover to these socioeconomic factors significantly improved the accuracy of the

Table 2A. Single and multiple linear regression models to predict prefectural male annual suicide rate (1970–2006)

	Single linear regression model			Multiple linear regression model		
	Coefficient	t	P value	Coefficient	t	P value
Land cloud cover	4.21	11.0	<0.001	3.83	7.14	<0.001
Sunshine	−0.30	−7.09	<0.001	−0.65	−1.41	0.158
Sun exposure time	−0.01	−7.05	<0.001	0.019	1.82	0.069
Population	-9.71×10^{-7}	−10.64	<0.001	-1.47×10^{-6}	−2.15	0.032
Population density	−0.002	−8.9	<0.001	0.001	1.66	0.097
Increase and decrease of population density	−8.10	−19.7	<0.001	−2.83	−5.60	<0.001
Prefectural income	-2.70×10^{-7}	−10.52	<0.001	3.28×10^{-7}	2.52	0.012
Working population	-1.53×10^{-6}	−9.59	<0.001	1.65×10^{-6}	2.79	0.005
Gain and loss of working population	−3.32	−18.46	<0.001	−0.121	−0.41	0.683
Employed population	-2.24×10^{-6}	−10.91	<0.001	-3.39×10^{-7}	−0.21	0.832
Gain and loss of employed population	−2.20	−15.25	<0.001	−0.80	−3.26	0.001
Income per employee	−0.003	−9.3	<0.001	−0.004	−8.56	<0.001
Gain and loss of income per employee	−1.03	−13.8	<0.001	−0.69	−9.29	<0.001
Per capita Income	−0.004	−11.4	<0.001	−0.004	−5.20	<0.001
Difference in per capita income from max prefecture's	−0.009	−23.6	<0.001	−0.002	3.94	<0.001
Unemployment	3.40	18.9	<0.001	2.19	10.97	<0.001
Gain and loss of unemployment	−2.64	4.10	<0.001	1.00	2.53	0.012

Table 2B. Single and multiple linear regression model to predict prefectural female annual suicide rate (1970–2006)

	Single linear regression model			Multiple linear regression model		
	Coefficient	t	P value	Coefficient	t	P value
Land cloud cover	0.67	5.00	<0.001	1.08	4.45	<0.001
Sunshine	−0.004	−0.28	0.78	0.07	0.32	0.747
Sun exposure time	−0.00006	−0.19	0.85	−0.0005	−0.10	0.919
Population	-1.05×10^{-7}	−3.26	0.001	7.41×10^{-7}	2.39	0.017
Population density	−0.0003	−3.57	<0.001	−0.0003	−1.81	0.070
Increase and decrease of population density	0.38	2.41	0.016	−0.49	−2.13	0.034
Prefectural income	-4.96×10^{-8}	−5.57	<0.001	2.27×10^{-7}	3.85	<0.001
Working population	-1.62×10^{-7}	−2.91	0.004	-1.65×10^{-7}	−0.61	0.539
Gain and loss of working population	−0.07	1.08	0.281	−0.34	−2.52	0.012
Employed population	-3.12×10^{-7}	−4.32	<0.001	-2.15×10^{-6}	−2.98	0.003
Gain and loss of employed population	0.29	5.58	<0.001	0.085	0.77	0.443
Income per employee	−0.002	−21.93	<0.001	−0.001	−5.68	<0.001
Gain and loss of income per employee	0.28	10.83	<0.001	0.0002	0.01	0.995
Per capita income	−0.002	−19.67	<0.001	−0.002	−5.52	<0.001
Difference of per capita income from max prefecture's	−0.0006	−3.91	<0.001	−0.0009	3.15	0.002
Unemployment	−0.38	−5.80	<0.001	−0.26	−2.89	0.004
Gain and loss of unemployment	−0.70	−3.38	0.001	−0.10	−0.56	0.578

model to predict suicide rates (likelihood ratio test : $P<0.0001$). For females, the variables strongly associated with suicide rate in the model ($R^2=0.37$) were land cloud cover, prefectural income, income per employee, per capita income, and difference in per capita income from the max prefecture's. In both the male and female models, variables showing strong associations ($P<0.001$) with age-adjusted suicide rates were land cloud cover, income per employee, per capita income, and the difference in per capita income from the max prefecture's. Even after the addition of calendar years as variables to the model, land cloud cover, but neither sunshine nor sun exposure time, remained significant (male : coefficient : 2.20 ; t : 4.04 ; $P < 0.001$; female : coefficient : 1.23 ; t : 4.75 ; $P < 0.001$).

DISCUSSION

In Japan, in 2007, the absolute number of suicide deaths and the suicide rates per 100,000 population of males and females were approximately 22,000 and 8,800 and 35.8 and 13.7, respectively. These suicide rates were less than those in Russia (58.1 and 9.8 [2005]), but greater than those in Canada (17.3 and 5.4 [2004]), Germany (19.7 and 6.6 [2004]), Italy (11.0 and 3.4 [2003]), the United Kingdom, 10.4 and 3.2 (2005), and the United States (17.7 and 4.5 [2005])[33]. The highest suicide rate in Japan was for persons aged 55 to 64 years[34]. Because Japan is a typical aging society, when adjusted for age, the recent suicide rates are not always the highest, and rates among females tended to decrease during the study period. We were able to confirm that unemployment and suicide rates, with or without age-adjustment, were highly correlated, as previously reported[5]. However, female age-adjusted suicide rates were inversely correlated with unemployment rates, a finding consistent with that of a previous study[35].

In addition, an increase in land cloud cover and a decrease in sun exposure time were associated with higher age-adjusted suicide rates, independent of economic variables, including unemployment rate, in all 3 models. Sunshine was a significant factor in the single linear regression analysis, but the P-value approached 0.05 in the multiple linear regression analysis. Sunshine is theoretically the reverse of land cloud cover, and we probably should have focused on land cloud cover rather than sunshine. A wide range of sunshine exposures tend to decrease the suicide rate[36–39] ; in contrast, an increase in sunshine of several days can trigger suicide[40–42], suggesting the effects of sunshine on suicide are extremely complicated. On the other hand, there have been no previous reports showing an association of land cloud cover with suicide.

In the present study, lower population density and its decrease compared with the previous year were associated with higher suicide rates even after adjustment for age, which is consistent with previous reports that suicide rates are often greater in rural areas[39,40]. In addition to unemployment rates, income per employee, and per capita income were negatively associated with suicide in both males and females, whereas differences in per capita income from the max prefecture's were positively associated with suicide in both males and females. Income per employee, change in income per employee, and differences in per capita income from the max prefecture's were associated with suicide. Thus, the time trend of economic factors and inequalities within Japan may also influence suicide. In European countries, the magnitude of inequalities between groups of higher and lower socioeconomic status appears to be attributable, in part, to causes of death related to smoking or alcohol use or those amenable to medical intervention[41,42]. Well-developed community mental-health services are associated with lower suicide rates than are services oriented toward inpatient treatments[43]. Thus, both economic and social factors in the community may be important in preventing suicide.

This study had several limitations. First, because this study was an ecological study conducted over a broad geographic area, we could not determine the precise mechanisms that lead to increased suicide rates. In particular, we did not have individual data, such as comorbidity of mental diseases. Second, in multivariate analysis shown in Tables 2A and 2B, we adjusted for population density and other urbanization factors using the following variables : population, increases and decreases in population density, prefectural income, working population, gain and loss of working population, employed population, gain and loss of employed population, income per employee, gain and loss of income per employee, per capita income, difference in per capita income from the max prefecture's, unemployment, gain and loss of unemployment. However, we could not adjust for all possible confounders, such as divorce rate and alcohol misuse. Moreover, there may be residual confounding in the variables listed above. Third, we used only sun-exposure-related variables, but not other factors, such as the amounts of rainfall and snow.

Conclusions

These results suggest that in addition to higher unemployment rates and other poor socioeconomic indices, more land cloud cover may increase age-adjusted suicide rates.

Competing Interests

The authors declare that they have no competing interests.

Acknowledgments : We thank Mr. Hiroki Sutou, HALEX Corporation, for data abstraction from the Japan Meteorological Agency, and Ms. Kiyomi Mashima and Michiyo Ogawa, medical students at The Jikei University School of Medicine, for data abstraction from the vital statistics of Japan.

References

1. WHO topics suicide http.//www.who.int/topics/suicide/en/[accessed 2008-01-15]
2. World Health Organization. Figures and facts about suicide. Geneva : WHO ; 1999. http.//www.who.int/mental_health/media/en/382.pdf [accessed 2008-01-15]
3. Chang SS, Gunnell D, Sterne JA, Lu TH, Cheng AT. Was the economic crisis 1997-1998 responsible for rising suicide rates in East/Southeast Asia ? A time-trend analysis for Japan, Hong Kong, South Korea, Taiwan, Singapore and Thailand. Soc Sci Med 2009 ; 68 : 1322-31.
4. Japan Ministry of Health, Labor and Welfare http.//www.mhlw.go.jp/toukei/saikin/hw/jinkou/kakutei07/hyo7.html [accessed 2008-01-15]
5. Inoue K, Tanii H, Abe S, Nishimura Y, Kaiya H, Nata M, et al. The report in the correlation between the factor of unemployment and suicide in Japan. Am J Forensic Med Pathol 2008 ; 29 : 202-3.
6. Kposowa AJ. Unemployment and suicide. a cohort analysis of social factors predicting suicide in the US National Longitudinal Mortality Study. Psychol Med 2001 ; 31 : 127-38.
7. Lewis G, Sloggett A. Suicide, deprivation, and unemployment. record linkage study. BMJ 1998 ; 317 : 1283-6.
8. Preti A, Miotto P. Suicide and unemployment in Italy, 1982-1994. J Epidemiol Community Health 1999 ; 53 : 694-701.
9. Johansson SE, Sundquist J. Unemployment is an important risk factor for suicide in contemporary Sweden. an 11-year follow-up study of a cross-sectional sample of 37,789 people. Public Health 1997 ; 111 : 41-5.
10. Ying YH, Chang K. A study of suicide and socioeconomic factors. Suicide Life Threat Behav 2009 ; 39 : 214-26.
11. Blakely TA, Collings SC, Atkinson J. Unemployment and suicide. Evidence for a causal association ? J Epidemiol Community Health 2003 ; 57 : 594-600.
12. Mortensen PB, Agerbo E, Erikson T, Qin P, Westergaard-Nielsen N. Psychiatric illness and risk factors for suicide in Denmark. Lancet 2000 ; 355 : 9-12.
13. Shah A, Bhandarkar R. Cross-national study of the correlation of general population suicide rates with unemployment rates. Psychol Rep 2008 ; 103 : 793-6.
14. Crombie IK. Can changes in the unemployment rates explain the recent changes in suicide rates in developed countries ? Int J Epidemiol 1990 ; 19 : 412-6.
15. Lin HC, Chen CS, Xirasagar S, Lee HC. Seasonality and climatic associations with violent and nonviolent suicide. a population-based study. Neuropsychobiology 2008 ; 57 : 32-7.
16. Reutfors J, Osby U, Ekbom A, Nordström P, Jokinen J, Papadopoulos FC. Seasonality of suicide in Sweden. Relationship with psychiatric disorder. J Affect Disord 2009 ; 119 : 59-65.
17. Ajdacic-Gross V, Lauber C, Sansossio R, Bopp M, Eich D, Gostynski M, et al. Seasonal associations between weather conditions and suicide—evidence against a classic hypothesis. Am J Epidemiol 2007 ; 165 : 561-9.
18. Rock D, Greenberg DM, Hallmayer JF. Increasing seasonality of suicide in Autralia 1970-1999. Psychiatry Res 2003 ; 120 : 43-51.
19. Heerlein A, Valeria C, Medina B. Seasonal variation in suicide deaths in Chile. Its relationship to latitude. Psychopathology 2006 ; 39 : 75-9.
20. Nejar KA, Bensenor IM, Lotufo PA. Sunshine and suicide at the tropic of Capricorn, Sao Paulo, Brazil, 1996-2004. Rev Saude Publica 2007 ; 41 : 1062-4.
21. Parker G, Gao F, Machin D. Seasonality of suicide in Singapore. Data from the equator. Psychol Med 2001 ; 31 : 549-53.
22. Petridou E, Papadopoulos FC, Frangakis CE, Skalkidou A, Trichopoulos D. A role of sunshine in the triggering of suicide. Epidemiology 2002 ; 13 : 106-9.
23. Ruuhela R, Hiltunen L, Venäläinen A, Pirinen P, Partonen T. Climate impact on suicide rates in Finland from 1971 to 2003. Int J Biometeorol 2009 ; 53 : 167-75.
24. Preti A, Lentini G, Maugeri M. Global warming possibly linked to an enhanced risk of suicide. data from

Italy, 1974–2003. J Affect Disord 2007 ; 102 : 19–25.
25. Kaufman YJ, Tanré D, Boucher O. A satellite view of aerosols in the climate system. Nature 2002 ; 419 : 215–23.
26. Allen MR, Ingram WJ. Constraints on future changes in climate and the hydrologic cycle. Nature 2002 ; 419 : 224–32.
27. Pierrehumbert RT. The hydrologic cycle in deep-time climate problems. Nature 2002 ; 419 : 191–8.
28. Huang Y, Dickinson RE, Chameides WL. Impact of aerosol indirect effect on surface temperature over East Asia. Proc Natl Acad Sci U S A 2006 ; 103 : 4371–6.
29. http.//www.ncnp.go.jp/ikiru-hp/genjo/toukei/pdf/08.pdf [accessed 2008–01–15]
30. http.//www.ncnp.go.jp/ikiru-hp/genjo/toukei/pdf/08.pdf [accessed 2008–01–15]
31. http.//www.data.jma.go.jp/obd/stats/etrn/index.php [accessed 2008–01–15]
32. http.//www.esri.cao.go.jp/jp/sna/toukei.html # kenmin [accessed 2008–01–15]
33. http.//www.who.int/mental_health/prevention/suicide/country_reports/en/ind.html [accessed 2008–01–15]
34. http.//www.who.int/mental_health/media/japa.pdf [accessed 2008–01–15]
35. Otsu A, Chinami M, Morgenthale S, Kaneko Y, Fujita D, Shirakawa T. Correlations for number of sunspots, unemployment rate, and suicide mortality in Japan. Percept Mot Skills 2006 ; 102 : 603–8.
36. Nishimura M, Terao T, Soeda S, Nakamura J, Iwata N, Sakamoto K. Suicide and occupation : further supportive evidence for their relevance. Prog Neuropsychopharmacol Biol Psychiatry 2004 ; 28 : 83–7.
37. Preti A. The influence of climate on suicidal behaviour in Italy. Psychiatry Res 1998 ; 78 : 9–19.
38. Souêtre E, Wehr TA, Douillet P, Darcourt G. Influence of environmental factors on suicidal behavior. Psychiatry Res 1990 ; 32 : 253–63.
39. Terao T, Soeda S, Yoshimura R, Nakamura J, Iwata N. Effect of latitude on suicide rates in Japan. Lancet 2002 ; 360 : 1892.
40. Papadopoulos FC, Frangakis CE, Skalkidou A, Petridou E, Stevens RG, Trichopoulos D. Exploring lag and duration effect of sunshine in triggering suicide. J Affective Disorders 2005 ; 55 : 287–97.
41. Petridou E, Papadopoulos FC, Frangakis CE, Skalkidou A, Trichopoulos D. A role of sunshine in the triggering of suicide. Epidemiology 2002 ; 13 : 106–9.
42. Salib E, Gray N. Weather conditions and fatal self-harm in North Cheshire 1989–1993. Br J Psychiatry 1997 ; 171 : 473–7.
43. Hirsch JK. A review of the literature on rural suicide. risk and protective factors, incidence, and prevention. Crisis 2006 ; 27 : 189–99.
44. Judd F, Cooper AM, Fraser C, Davis J. Rural suicide—people or place effects? Aust N Z J Psychiatry 2006 ; 40 : 208–16.
45. Mackenbach JP, Stirbu I, Roskam AJ, Schaap MM, Menvielle G, Leinsalu M, et al. Socioeconomic inequalities in health in 22 European countries. N Engl J Med 2008 ; 358 : 2468–81.
46. Mackenbach JP, Kunst AE, Cavelaars AE, Groenhof F, Geurts JJ. Socioeconomic inequalities in morbidity and mortality in western Europe. The EU Working Group on Socioeconomic Inequalities in Health. Lancet 1997 ; 349 : 1655–9.
47. Pirkola S, Sund R, Sailas E, Wahlbeck K. Community mental-health services and suicide rate in Finland. a nationwide small-area analysis. Lancet 2009 ; 373 : 147–53.

Appendix. Correlation matrix of variables

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
1	1.0																
2	−0.9	1.0															
3	−0.9	1.0	1.0														
4	−0.2	0.1	0.1	1.0													
5	−0.2	0.1	0.1	0.9	1.0												
6	−0.2	0.2	0.3	0.4	0.3	1.0											
7	−0.2	0.1	0.1	1.0	0.9	0.3	1.0										
8	−0.2	0.1	0.1	1.0	0.9	0.3	1.0	1.0									
9	−0.1	0.1	0.1	0.2	0.1	0.5	0.1	0.2	1.0								
10	−0.2	0.1	0.1	1.0	0.9	0.3	1.0	1.0	0.2	1.0							
11	−0.1	0.1	0.1	0.0	0.0	0.5	−0.0	−0.0	0.9	0.0	1.0						
12	−0.2	0.0	0.0	0.6	0.6	0.1	0.6	0.6	−0.0	0.6	−0.2	1.0					
13	−0.1	0.1	0.1	0.0	0.0	0.3	−0.0	0.0	0.3	−0.0	0.3	−0.3	1.0				
14	−0.0	−0.1	−0.1	0.6	0.5	0.1	0.7	0.6	0.1	0.6	−0.1	0.9	−0.2	1.0			
15	0.2	−0.3	−0.3	−0.6	−0.6	−0.6	−0.6	−0.6	−0.3	−0.6	−0.2	−0.3	−0.3	−0.5	1.0		
16	0.0	−0.0	−0.0	0.2	0.2	−0.2	0.2	0.1	−0.4	0.2	−0.5	0.3	−0.6	0.1	0.4	1.0	
17	−0.0	−0.0	−0.0	0.0	0.0	0.1	0.0	0.0	−0.0	0.0	−0.0	0.2	−0.0	0.1	−0.1	−0.1	1.0

1 : Land cloud cover ; 2 : Sunshine ; 3 : Sun exposure time ; 4 : Population ; 5 : Population density ; 6 : Increase and decrease of population density ; 7 : Prefectural income ; 8 : Working population ; 9 : Gain and loss of working population ; 10 : Employed population ; 11 : Gain and loss of employed population ; 12 : Income per employee ; 13 : Gain and loss of income per employee ; 14 : Per capita income ; 15 : Difference of per capita income from max prefecture's ; 16 : Unemployment ; 17 : Gain and loss of unemployment