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Article

Suicide Overall and Suicide by Pesticide among South Korean Workers: A 15-Year Population-Based Study

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Abstract: Suicide is a major public health concern in South Korea, and self-poisoning by pesticides is one of the common methods of suicide. Pesticide ban policies have been successful for suicide prevention; however, no studies have shown their effect according to occupational groups. The present study analyzed suicide and suicide by pesticide rates among South Korean workers age 15-64 in 2003-2017, their associations with occupational groups, and the impact of three major economic indices on these factors. Workers in the agriculture, forestry, and fishery industries have relative risks of 5.62 (95% CI: 5.54-5.69) for suicide overall and 25.49 (95% CI: 24.46-26.57) for suicide by pesticide. The real gross domestic product (RGDP) has a positive association with suicide overall only in the last five-year period investigated in this study, and the unemployment rate consistently has a positive association. The economic status and policy for suicide prevention affect suicide and suicide by pesticide rates differently among occupational groups and different time periods. Policy addressing suicidal risk for different occupational groups should be of concern in South Korea.

Keywords: suicide rate; suicide by pesticide; occupational group; suicide prevention; South Korea; population-based study

1. Introduction

South Korea has one of the highest suicide rates, and the situation has gotten worse in the past decades. The suicide rate of South Korea was 148 per 1,000,000 in 2000 and increased to 283 per 1,000,000 in 2015.[1] Therefore, many kinds of governmental and political interventions for suicide prevention have been introduced. Mainly, they focused on the youth and the elderly by providing education and welfare.[2-5] Moreover, restrictions on the methods of suicide were effective for prevention.[6]

Self-poisoning by highly toxic pesticides such as the Paraquat is a common suicidal method, so political intervention has been actively adopted in agricultural countries, including Sri Lanka and Bangladesh, and also in high-income countries, including the UK and South Korea.[7-12] The complete ban of highly toxic pesticides, introduced in November 2012, has effectively decreased both the suicide by pesticide and overall suicide rates in South Korea.[7,13-15] The World Health Organization has confirmed that it is one of the most successful policies for suicide prevention.[16]

Furthermore, sociodemographic factors like age, sex, and occupation affect the suicide rate. Men are more vulnerable than women, and older people are much riskier than younger; that is, the

male suicide rate of South Korea (371 per 1,000,000) was two-fold that of the female rate (177 per 1,000,000), and that of people over the age of 70 was 1,160 per 1,000,000 in 2012.

Additionally, occupation affects suicide.[17,18] People with occupations show lower suicide ideation and suicide rates than people without occupations, and specific occupational groups, such as agriculture, forestry, and fishery, have worse conditions than other groups.[19-22] There is a social discrepancy in occupational groups, which makes suicide rates different.[17,19,22]

Besides personal variables, societal circumstances are also crucial factors. The three major economic indicators, which are the real gross domestic product (*RGDP*), the unemployment rate (*UnR*), and the customer price index (*CPI*), represent the status of a country. They have an association with suicide ideation, suicide attempts, and suicide of South Korea and Western countries.[23-26] In addition, the economic crisis of the late 1990s in Asia and 2008 worldwide were inflection points in the surge of suicide.[27,28]

However, there are no satisfactory results about *the suicide and suicide by pesticide rate trends and the effect of suicide prevention by occupational groups*. It is reasonable to assume that policies for suicide prevention have different effects on each occupational group because pesticides are primarily related to the agriculture, forestry, and fishery industries. In this study, we analyze the association of ecological factors, including the time before and after the pesticide ban policy was introduced and the other factors mentioned above, with 15-year suicide rates. We show that suicide by pesticide and overall suicide rates of workers in the agriculture, forestry, and fishery group are higher than other occupational groups and even the general population, and the effect of pesticide ban policy is also more significant.

2. Materials and Methods

2.1. Data Sources

All data used in this study was extracted from the microdata provided by the Korean National Statistical Office (KNSO, https://mdis.kostat.go.kr) on July 15, 2019. The target years are the 15-year period from 2003 to 2017, and the target age is the range from 15 to 64, which is the working-age population defined by the International Labor Organization (ILO).[29] Populations by occupational groups were collected from the Economically Active Population Survey (EAPS), which investigates economic activity for sample households, and the information of deaths from the National Death Records (NDR), which is the official record of deaths in South Korea. The cause of death was recorded by the International Classification of Diseases 10th edition (ICD-10) in the NDR.

The economic indicators were from the Korean Statistical Information Service (KOSIS, https://kosis.kr). The *RGDP* is a percent of the rate of the nominal gross domestic product from one year to another, the *UnR* is a percent of the sum of people who wanted to get a job in the last four weeks but could not divided by the reference population, and the *CPI* is the relative prices of selected main customs to those in the reference year.[23,30] In the present study, we used the rate of the CPI from one year to another instead of the CPI itself because the CPI always increases by year as is characteristic, and the rate is a better fit to time trend analysis.

2.2. Study Population

Deaths by suicide were classified by ICD-10 codes: intentional self-harm (X60-X84), sequel of intentional self-harm (Y87.0), and suicide by pesticide (X68). The total number of suicides and suicide by pesticides by year is shown in Supplementary Tables S1 and S2.

The ILO defines a *worker* as a person who worked for longer than an hour in the past week. There are some differences in the definition of workers by the KNSO and the ILO. In the present study, the ILO definition was adopted to calculate consistent estimations from the 15-year data. The population of each occupational group is shown in Supplementary Table S3.

Occupations were classified into five groups based on the Korean Standard Occupational Classification 6th edition; they are 1) managers and professionals *(M-P)*, 2) officers and workers in

services and trades *(O-S-T)*, 3) workers in agriculture, forestry, and fishery *(A-F-F)*, 4) skilled manual labor workers *(SKL)*, and 5) unskilled manual labor workers *(USL)*.

Finally, the reference population used for statistical analysis came from the Korea National Consensus Survey (KNCS), which includes workers and non-workers aged 15-64. The KNCS measured the population once every five years (2005, 2010, and 2015), so the 2005 population was used as a reference for 2003-2007, 2010 for 2008-2012, and 2015 for 2013-2017.

2.3. Statistical Analysis

The number of workers in South Korea by sex, age, and occupation was estimated using the microdata from the EAPS. The EAPS from sample households were conducted each month, so the total number can be estimated by adjusting weights. Data on suicide and pesticide-use suicide collected from the NDR also had their sociodemographic characteristics recorded.

The present study calculated the crude mortality rate (*CMR*) as the number of deaths from the NDR divided by the population from the EAPS matched for their age, sex, and job and converted it to units per 1,000,000. This rate is not a cohort statistical result, but a hypothetical formula based on population-based studies. It resulted in the standardized mortality ratios (*SMRs*) for the observed deaths in a population for the specific sex, 5-year age category, and occupation groups divided by the expected values estimated by the deaths of the reference population in each sex and age group. By this calculation, it is possible to directly compare specific occupational groups and the general population. If the mortality rate is the same as the reference, the value of SMR would be 100.

The 95% confidence intervals (CIs) were calculated by the Vandenbroucke method, which provides the CIs through shortcuts. The Vandenbroucke method, whose assumption is that the deaths show a Poisson distribution, is proper for dealing with a large number (>20) of deaths and creates simple approximations for comparison.[31]

Regression analyses were performed to show associations between suicide rates and personal and social factors. The crude rates of the specific population were the outcome variables, which were expected to have a Poisson distribution, and the other factors were the predictor variables. This method was used to analyze the trend of occupational diseases in previous studies.[32] First, the logistic regression models for occupational groups stratified with age and sex were calculated. As a result, relative risks (RRs) are determined for each occupational group compared to SKL over the 15-year period death statistics. Moreover, the linear regression models were made for economic indicators by each year stratified with occupational groups. These models showed the effect of social factors on the suicide and suicide by pesticide rates by occupation and the time trend of the effect. All statistical and mathematical analyses were performed by the statistical software R version 3.6.1 (2019-07-05).[33]

2.4. Ethics Statement

The present study was approved by the Institutional Review Board of Hanyang University (HYU-2019-06-013) and only data without personal identifiers from the KNSO was used.

3. Results

3.1. Standardized Mortality Ratios and Crude Mortality Rates of Suicide and Suicide by pesticide

All SMRs and CMRs of the workers aged 15-64 for suicide and suicide by pesticide by year are summarized in Table 1. The time trends of SMRs over the 15-year period are visualized in Figure 1. CMRs for all working-age populations, including workers and non-workers, are listed in Supplementary Tables 4 and 5 and shown in Supplementary Figures 1 and 2.

There is a dramatic decrease in the CMR of suicide overall from 2005 to 2006 (-16.5%), with the lowest point occurring in 2006 (129 per 1,000,000). However, the rate worsens after three years; the CMR shows its two highest peaks in 2009 and 2013 (191 and 194 per 1,000,000). After 2013, it goes slightly down to 161 per 1,000,000 in 2017. The SMR of suicide overall, which is a marker comparing workers to the general population, shows a different pattern. It starts with 65.4 in 2003, directs

downward until 2007 at 53.7 (95% CI: 51.8-55.7), and flattens from 2008 at 55.3 (95% CI: 53.5-57.3) to 2012 at 58.8 (95% CI: 57.0-60.6). Nevertheless, it surges in 2013 (+13.8%) and decreases between 2016 and 2017 (-4.2%).

The trend of suicide by pesticide CMRs diminishes through the 15-year period. It achieved a decrease every year from 2003 to 2017 (-90.9%, 55 to 5 per 1,000,000). On the contrary, the SMRs of suicide by pesticide showed a complex fluctuation. The lowest point is in 2007 at 61.5 (95% CI: 57.0-66.2) and two peaks are seen in 2009 at 70.0 (95% CI: 64.8-75.4) and 2013 at 78.1 (95% CI: 69.6-87.2).

Table 1. The standardized mortality ratios (SMRs) and crude mortality rates (CMRs) per 10,000,000 of suicide overall and suicide by pesticide by year among workers age 15-64.

Year	Suicide Overall		Suicide by pesticide	
	SMR[1]	CMR[2]	SMR[1]	CMR[2]
2003	65.4 (63.2-67.7)	159 (153.9-164.8)	72.1 (68.0-76.4)	55 (52.5-59.0)
2004	63.7 (61.5-65.9)	158 (153.2-164.0)	70.3 (66.3-74.5)	54 (51.6-58.0)
2005	59.2 (57.1-61.2)	154 (149.5-160.2)	65.7 (61.4-70.1)	42 (39.3-44.9)
2006	55.9 (53.8-58.0)	128 (123.7-133.4)	63.0 (58.5-67.8)	33 (31.0-36.0)
2007	53.7 (51.8-55.7)	140 (135.2-145.3)	61.5 (57.0-66.2)	33 (30.5-35.4)
2008	55.3 (53.5-57.3)	147 (142.8-152.9)	63.7 (59.0-68.7)	30 (27.7-32.3)
2009	57.9 (56.1-59.6)	191 (185.3-196.9)	70.0 (64.8-75.4)	30 (28.5-33.1)
2010	56.2 (54.5-58.0)	186 (180.8-192.2)	63.7 (58.6-68.9)	26 (24.5-28.8)
2011	54.6 (52.9-56.2)	186 (181.0-192.3)	65.2 (60.1-70.6)	26 (24.4-28.6)
2012	58.8 (57.0-60.6)	177 (171.5-182.5)	62.2 (56.5-68.2)	19 (17.5-21.1)
2013	66.9 (65.0-68.9)	194 (189.2-200.6)	78.1 (69.6-87.2)	13 (11.7-14.7)
2014	66.0 (64.1-68.0)	189 (183.6-194.7)	74.2 (64.7-84.5)	9 (8.0-10.4)
2015	67.7 (65.6-69.7)	179 (173.9-184.8)	68.9 (58.8-79.9)	7 (6.0-8.2)
2016	67.1 (65.1-69.2)	175 (169.6-180.3)	67.5 (57.4-78.4)	6 (5.8-7.9)
2017	64.3 (62.2-66.3)	161 (156.5-166.8)	63.1 (52.6-74.6)	5 (4.4-6.3)

[1]The ratio of the mortality of workers age 15-64 to the general population age 15-64, including workers and non-workers. The 95% confidence intervals are calculated by the Vandenbroucke method.[31] [2]The number of death determined assuming the population is 1,000,000.

Moreover, we can confirm the age and sex effect on the suicide and suicide by pesticide rates of workers, which was observed in the general population. The CMRs are always higher for men and the old compared to women and the young (Supplementary Tables 4 and 5).

However, the SMR of suicide overall by age group shows a peculiar trend. From 2003 to 2010, intervals between those aged 15-39 and those age 40-64 become close, and finally, the SMRs were similar in 2011. After 2013, the difference was inversed in that the young become larger than the old until 2017.

3.2. The Time Trend and Relative Risks for Occupational Groups

For suicide overall, the SMRs and the CMRs do not change significantly with the O-S-T and SKL groups (Figure 2). The A-F-F group always showed the highest values, and the SMRs are larger than 100 each year; the suicide rate of the A-F-F is worse than the general population. The M-P groups slightly increase through the 15-year period, both in the SMRs and the CMRs; the SMR increases +274.0% from 18.0 (95% CI: 14.7-21.7) in 2003 to 67.4 (95% CI: 63.0-72.0) in 2017, and the CMR increases +237.0% from 46 (95% CI: 37.8-56.0) in 2003 to 155 (95% CI: 145.3-166.1) in 2017.

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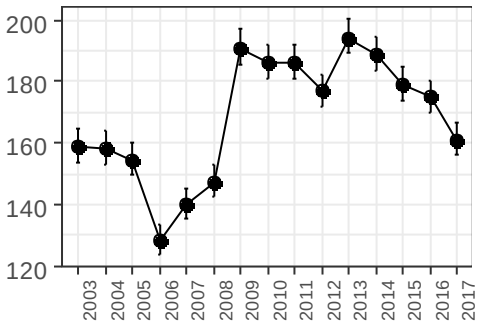
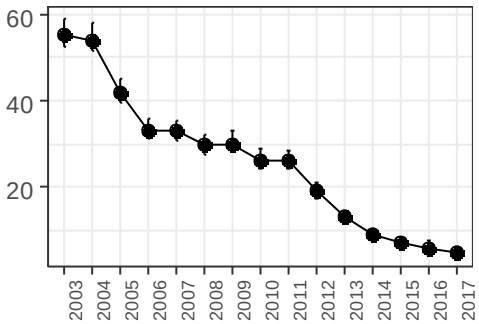
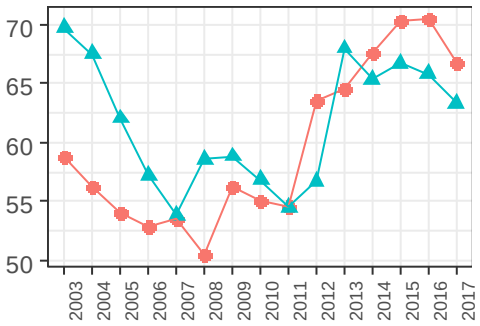


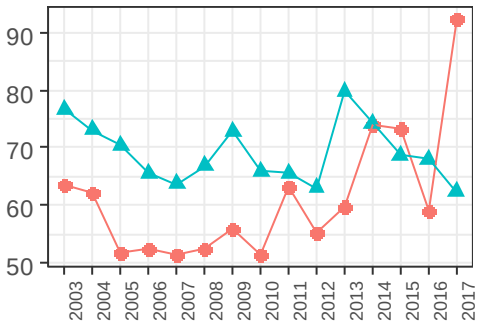
(a) *Crude mortality rates* of suicide overall



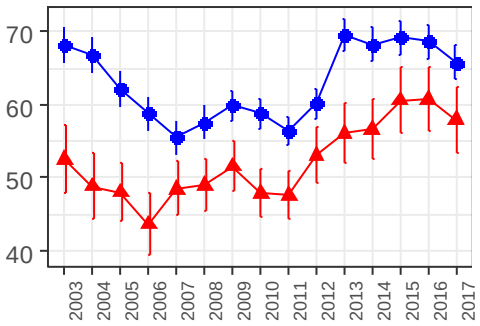
(d) *Crude mortality rates* of suicide by pesticide



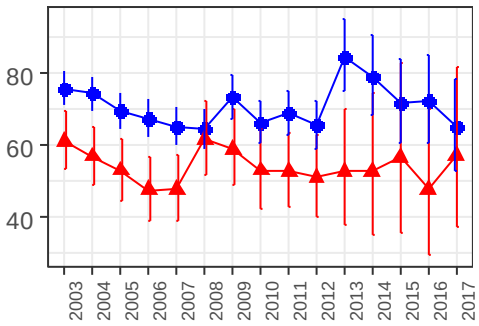
(b) Overall suicide *SMRs* by age (**Pink:** 15-39, **Green:** 40-64)



(e) Suicide by pesticide *SMRs* by age (**Pink:** 15-39, **Green:** 40-64)



(c) Overall suicide *SMRs* by sex (**Blue:** male, **Red:** female)



(f) Suicide by pesticide *SMRs* by sex (**Blue:** male, **Red:** female)

Figure 1. Time trends of crude mortality rates and standardized mortality ratios of suicide and suicide by pesticide among workers age 15-64. Figures in the left column deal with suicide overall and those on the right column with suicide by pesticide. **(a)** Crude rates of overall suicide. **(b)** Overall suicide SMRs by age (**Pink:** 15-39, **Green:** 40-64). **(c)** Overall suicide SMRs by sex (**Blue:** male, **Red:** female). **(d)** Crude rates of suicide by pesticide. **(e)** Suicide by pesticide SMRs by age (**Pink:** 15-39, **Green:** 40-64). **(f)** Suicide by pesticide SMRs by sex (**Blue:** male, **Red:** female).

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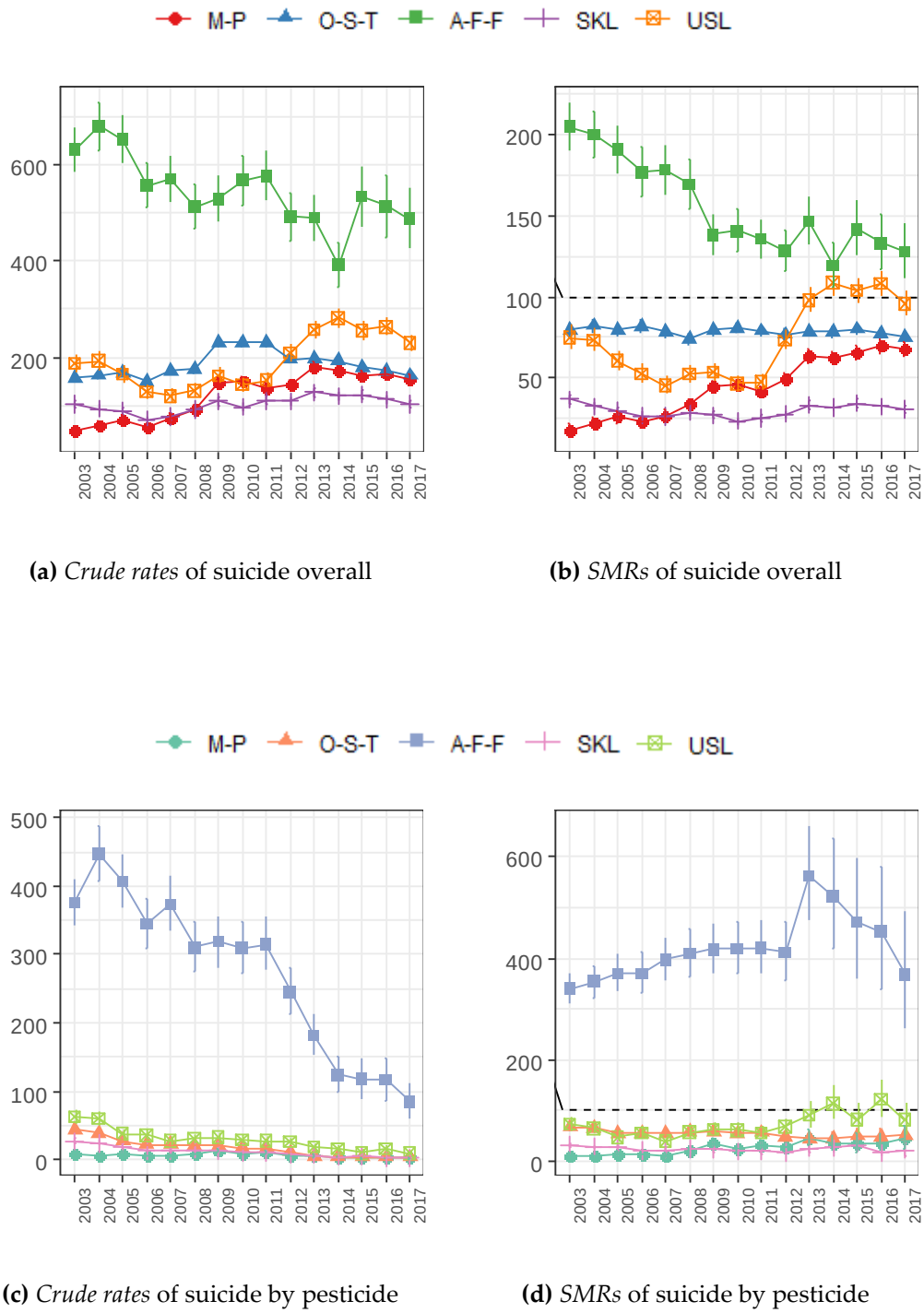

(a) *Crude rates* of suicide overall

(b) *SMRs* of suicide overall

(c) *Crude rates* of suicide by pesticide

(d) *SMRs* of suicide by pesticide

Figure 2. Time trends of suicide and suicide by pesticide rates by occupational groups among workers age 15-64. The first row represents suicide overall and the second row represents suicide by pesticide. The left column shows the crude mortality rates and the right one shows the standardized mortality ratios (SMRs). **M-P:** Manager-Professional, **O-S-T:** Officer-Service-Trade, **A-F-F:** Agriculture-Forestry-Fishery, **SKL:** Skilled manual labor, **USL:** Unskilled manual labor. **(a)** Crude rates of suicide overall. **(b)** SMRs of suicide overall. **(c)** Crude rates of suicide by pesticide. **(d)** SMRs of suicide by pesticide.

Table 2. Relative risks for suicide and suicide by pesticide with age-sex stratification by occupational group to the skillful manual labor group among workers age 15-64.

Strata[1]	Predictors[2]	Overall RR[3]	95% CI	Pesticide RR[4]	95% CI
All	(Intercept)	78.46*	77.46 – 79.46	7.76*	7.45 – 8.08
	M-P	1.44*	1.42 – 1.47	0.83*	0.78 – 0.88
	O-S-T	2.44*	2.40 – 2.47	2.78*	2.65 – 2.91
	A-F-F	5.62*	5.54 – 5.69	25.49*	24.46 – 26.57
	USL	2.24*	2.21 – 2.28	3.08*	2.94 – 3.23
Young Male	(Intercept)	85.85*	83.77 – 87.97	4.33*	3.88 – 4.82
	M-P	0.82*	0.79 – 0.85	0.52*	0.43 – 0.63
	O-S-T	1.88*	1.82 – 1.94	2.35*	2.07 – 2.68
	A-F-F	5.89*	5.74 – 6.05	37.16*	33.35 – 41.57
	USL	2.05*	1.99 – 2.11	3.84*	3.40 – 4.34
Old Male	(Intercept)	136.79*	134.16 – 139.45	20.65*	19.64 – 21.70
	M-P	1.92*	1.88 – 1.97	0.88*	0.82 – 0.94
	O-S-T	3.3*	3.23 – 3.38	3.01*	2.84 – 3.19
	A-F-F	5.69*	5.58 – 5.82	18.46*	17.55 – 19.43
	USL	3.17*	3.10 – 3.24	3.4*	3.21 – 3.60
Young Female	(Intercept)	69.03*	67.16 – 70.92	2.95*	2.58 – 3.35
	M-P	0.65*	0.62 – 0.68	0.51*	0.40 – 0.63
	O-S-T	1.26*	1.22 – 1.31	1.32**	1.11 – 1.57
	A-F-F	3.64*	3.53 – 3.75	39.73*	34.86 – 45.53
	USL	0.93**	0.90 – 0.97	1.13	0.94 – 1.35
Old Female	(Intercept)	22.16*	21.11 – 23.24	3.09*	2.71 – 3.51
	M-P	3.36*	3.18 – 3.55	1.21**	1.01 – 1.44
	O-S-T	2.9*	2.74 – 3.07	3.22*	2.78 – 3.73
	A-F-F	10.23*	9.73 – 10.76	42.5*	37.41 – 48.54
	USL	1.33*	1.25 – 1.42	1.78*	1.52 – 2.09

[1]Young corresponds to 15 to 39 years old and old corresponds to 40 to 64 years old. [2]**M-P:** Manager-Professional, **O-S-T:** Officer-Service-Trade, **A-F-F:** Agriculture-Forestry-Fishery, **USL:** Unskilled manual labor. [3]Relative risks of the crude mortality rate for suicide. [4]Relative risks of the crude mortality rate for suicide by pesticide. *The p-value is under 0.001. **The p-value is under 0.05.

Furthermore, the USL group shows an enormous increment in both the SMR and CMR of suicide overall between 2011 and 2013: 47.5 (95% CI: 43.1-52.2) to 98.1 (95%CI: 90.8-105.7) in the SMR, and 152 to 257 per 1,000,000 in the CMR. In 2014, the SMR of the USL group reached over 100. For suicide by pesticide, the A-F-F workers have much more significant behavior than other workers, and the CMR goes down over the 15-year period while the SMR fluctuates irregularly.

Table 2 summarizes the RRs for each occupational group by synthesizing all death data through the 15-year period (Table 2). Moreover, stratification was performed to confirm the effect on age and sex; the strata are young male, old male, young female, and old female, where the young corresponds to people age 15-39 and the old corresponds to people age 40-64. The time trends of SMRs and CMRs by occupational groups over the 15-year period are shown in Figure 2.

The SKL group shows the lowest suicide rate, so it was set as the reference for analyses. For all occupational groups without stratification, the A-F-F group has the highest RR for suicide overall, 5.62 (95% CI: 5.54-5.69), followed by O-S-T and USL. The M-P group shows the lowest value, 1.44 (95% CI: 1.42-1.47). A-F-F also has the highest RR for suicide by pesticide, 25.49 (95% CI: 24.46-26.57), followed by the USL and O-S-T groups; however, only the M-P group has a lower risk than SKL, 0.83 (95%CI: 0.78-0.88). The A-F-F group record the highest value of suicide and suicide by pesticide rates in all strata, and the young male and young female strata represent the M-P groups with the lowest RR for suicide and suicide by pesticide.

3.3. The Impacts of Suicide Prevention and Economic Indicators on Suicide and Suicide by pesticide

First of all, we confirmed the effect of time flow by estimating RRs for the five-year periods of 2008-2012 and 2013-2017, with reference to the first five-year period of 2003-2007, without any variables. This estimation shows the only effect of time on suicide and suicide by pesticide. In the third five-year period, it can be assumed that the effect of the pesticide ban policy for suicide prevention occurred. The overall suicide rate for all occupations does not change over the 15-year period, that is, RR of 2008-2012 is 0.95 (95% CI: 0.94-0.96) and 2013-2017 is 1.01 (95% CI: 1.00-1.02). However, the suicide by pesticide rate apparently decreases; RR of 2008-2012 is 0.60 (95% CI: 0.59-0.61) and 2013-2017 is 0.22 (95% CI: 0.22-0.23). Additionally, the overall suicide rate of the M-P group showed an enormous increase with time; RR of 2008-2012 is 2.18 (95% CI: 2.11-2.25) and 2013-2017 is 2.66 (95% CI: 2.58-2.74). The SKL group also shows an increase.

Generalized linear regression models are used as indicators of the association between suicide and suicide by pesticide, and three major economic indicators, which are RGDP, UnR, and CPI, are considered with the effect of time. The time trends of these indices are shown in the Supplementary Table. These models show interactions with time per year, so regressions are divided by each five-year period, with the first as 2003-2007, the second 2008-2012, and the third 2013-2017. The SKL group has the lowest RR, and the A-F-F group has the highest RR for the models. The calculated β values are tabulated in Table 4, and an overview is presented in Figure 3.

For the overall suicide rate of all occupational groups, the RGDP shows no significant effect on the first and second five-year periods (β_{GDP}=-0.03 and 0.00) but a positive association in the last five-year period (β_{GDP}=0.34), the UnR represents positive associations for each five-year period (β_{UnR}=0.15, 0.27 and 0.06), and the CPI has a positive association in the first five-year period (β_{CPI}=0.16) but changes to a negative association in the last period (β_{GDP}=-0.27). These patterns repeat in the overall suicide rate of the A-F-F group similarly. However, the SKL has a different trend; the effect of UnR is negative in the first period (β_{GDP}=-0.20) and not statistically significant in the other periods.

Macroeconomic indicators affect suicide by pesticide differently compared to suicide overall. The positive associations of RGDP become huge in the last five-year period (β_{GDP}=1.26 for all occupations, β_{GDP}=1.20 for SKL, and β_{GDP}=1.29 for A-F-F). The UnR and CPI show strong negative associations with suicide by pesticide only in the last five-year period.

Table 3. Relative risks by a simple logistic regression model using the crude mortality rate over each five-year period. The reference is the first five-year period, 2003-2007.

Jobs[1]	Relative Risks for Suicide Overall		Relative Risks for Suicide by pesticide	
	2008-2012	2013-2017	2008-2012	2013-2017
All	0.95* (0.94 – 0.96)	1.01** (1.00 – 1.02)	0.60* (0.59 – 0.61)	0.22* (0.22 – 0.23)
M-P	2.18* (2.11 – 2.25)	2.66* (2.58 – 2.74)	1.83* (1.65 – 2.04)	0.69* (0.60 – 0.79)
O-S-T	1.15* (1.13 – 1.17)	0.93* (0.91 – 0.95)	0.53* (0.50 – 0.56)	0.12* (0.11 – 0.13)
A-F-F	0.69* (0.68 – 0.70)	0.67* (0.66 – 0.68)	0.59* (0.58 – 0.60)	0.22* (0.22 – 0.23)
SKL	1.22* (1.18 – 1.26)	1.27* (1.23 – 1.31)	0.49* (0.44 – 0.53)	0.15* (0.13 – 0.17)
USL	1.05* (1.03 – 1.07)	1.64* (1.61 – 1.67)	0.65* (0.62 – 0.68)	0.29* (0.27 – 0.31)

[1] **M-P:** Manager-Professional, **O-S-T:** Officer-Service-Trade, **A-F-F:** Agriculture-Forestry-Fishery, **SKL:** Skilled manual labor, **USL:** Unskilled manual labor. *The p-value is under 0.001. **The p-value is under 0.05.

Table 4. Linear regression models for suicide and suicide by pesticide with job stratification by the economic indicators for each five-year period.

Job[1]	Year	Model for Suicide Overall[2]				Model for Suicide by pesticide[3]			
		β_0	β_{GDP}	β_{UnR}	β_{CPI}	β_0	β_{GDP}	β_{UnR}	β_{CPI}
All	2003-2007	4.38*	-0.03*	0.15*	0.16*	2.43*	0.03*	0.27*	0.30*
	2008-2012		-0.00	0.27*	-0.03*		-0.02*	0.32*	0.13*
	2013-2017		0.34*	0.06*	-0.27*		1.26*	-0.67*	-0.79*
SKL	2003-2007	4.33*	-0.00	-0.20*	0.21*	1.22**	-0.07**	0.06	0.52*
	2008-2012		-0.04*	0.08	-0.02		-0.06**	-0.07	0.34*
	2013-2017		0.20*	-0.06	-0.23*		1.20*	-0.74*	-1.23*
A-F-F	2003-2007	4.83*	-0.04*	0.28*	0.22*	3.78*	0.05*	0.28*	0.25*
	2008-2012		0.01*	0.28*	0.03*		-0.01*	0.30*	0.14*
	2013-2017		0.18*	0.25*	-0.31*		1.29*	-0.67*	-0.85*

[1]**SKL:** Skilled manual labor, **A-F-F:** Agriculture-Forestry-Fishery [2]Generalized linear regression model for the crude mortality rate for suicide. [3]Generalized linear regression model for the crude mortality rate for suicide by pesticide. *The p-value is under 0.001. **The p-value is under 0.05.

4. Discussion

The present study investigated suicide among South Korean workers in 2003-2017. The CMR for suicide overall shows a considerable increase between 2008 and 2009 and a slight one between 2011 and 2013. However, the general population has a different pattern with an enormous increase between 2008 and 2009, followed by a continuous decrease in a previous study.[4] The suicide rate among the elderly aged over 70 diminished significantly due to active suicide preventions for them, such as phone-based interventions and programs by the Mental Health Welfare Center.[3]

However, the overall suicide rate among the general population of men age 30-40 increased in 2011 and 2013; there was no targeted policy for them.[4,5] Similarly, suicide prevention for workers was weaker than for the elderly, so this could result in the suicide rate of workers showing an increment while that of the general population decreased.[34]

The SMR shows a direct comparison of the characteristics to workers in the working-age population to the general population at the same age; it is not an absolute value but a relative one, where the number of deaths in the general population is set to 100.[31] In general, people with occupations are less risky for suicide than people without occupations.

The SMR of suicide overall went down from 2003 to 2007, decreasing from 65.4 (95% CI: 63.2-67.7) to 53.7 (95% CI: 51.8-55.7), and surged from 2011 to 2015, increasing from 54.6 (95% CI: 52.9-56.2) to 67.7 (95% CI: 65.6-69.7). Furthermore, the SMR of older people (40-64 years old), was larger than that of younger people (15-39 years old), until 2011; however, the young are riskier than the old after 2014. In regard to gender, men are always more suicidal than women, even among workers. These are unique trends not similar to any of those in the general population.

Through the recent fifteen years, the CMR of suicide by pesticide among South Korean workers of the working-age population has continuously decreased. At first, the present study confirms that the pesticide ban policy has had a good effect on suicide by pesticide in workers as in the general population.[7,13-15] In a previous study, the age-standardized suicide by pesticide rate among the general population in South Korea went down from 2011 to 2013: 5.26 to 2.67 per 1,000,000; the complete regulation of highly toxic pesticides was introduced in 2012.[13,14] This reduction is significant in men, the elderly, and rural residents. Additionally, pesticide ban policies have been successful in other countries; a meta-analysis proved that national bans of specific pesticides in six countries, including South Korea, show consistent results concerning decreases in suicide by pesticide.[7,9,12-14,35,36]

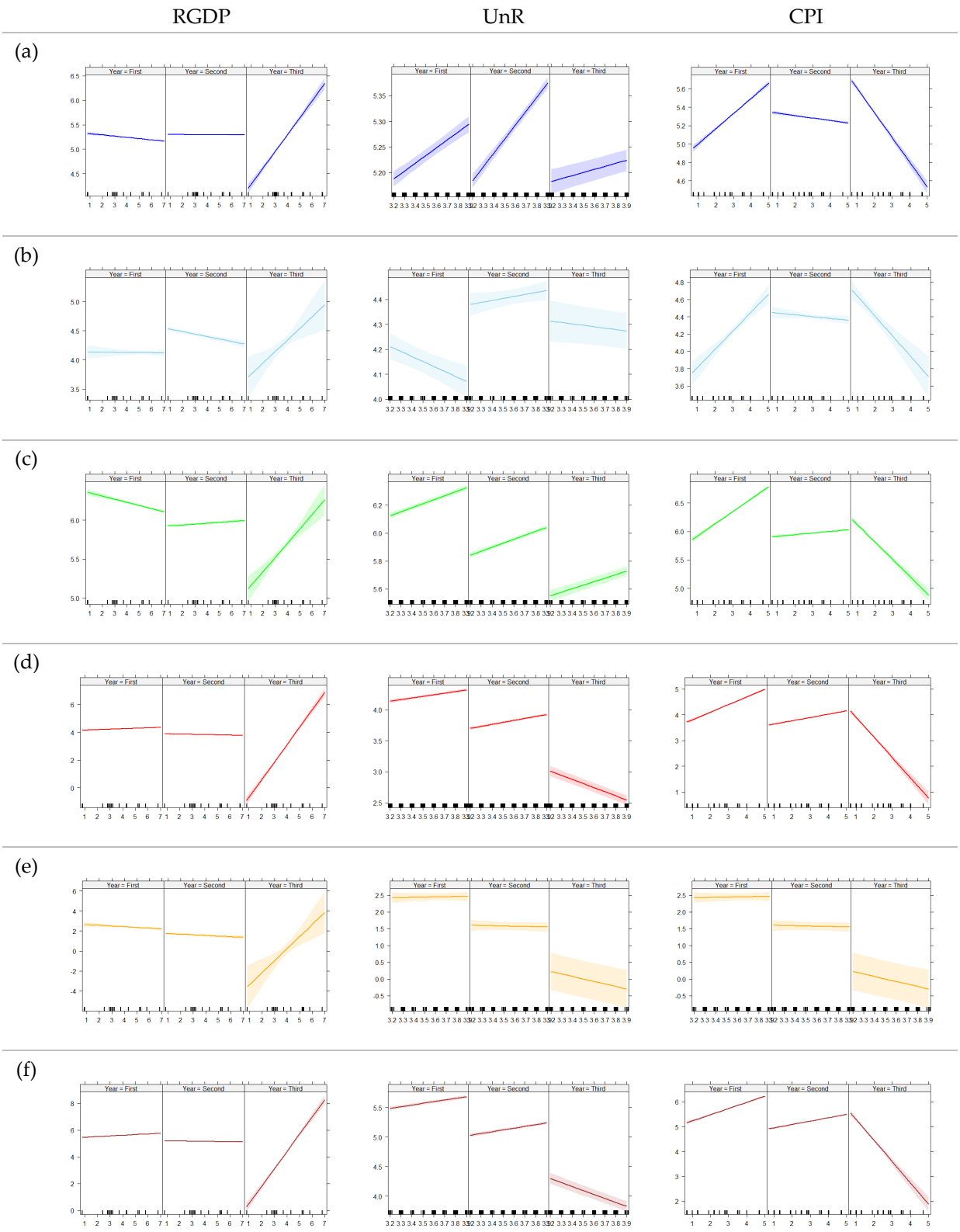

Figure 3. Summary of the general linear regression models for suicide and suicide by pesticide by economic indicators. Each model shows each occupational group divided by each five-year period (2003-2007, 2008-2012, and 2013-2017). **RGDP:** real gross domestic product. **UnR:** unemployment rate. **CPI:** rate of customer price index. **(a)** Overall suicide rate for all occupational groups. **(b)** Overall suicide rate for the skillful manual labor group. **(c)** Overall suicide rate for agriculture, forestry and fishery. **(d)** Suicide by pesticide for all occupational groups. **(e)** Suicide by pesticide for the skillful manual labor group. **(f)** Suicide by pesticide for agriculture, forestry and fishery.

The present study also finds that more considerable reductions among South Korean workers in men, age 40-64, and after 2013 than female, age 15-39, and before 2011. In contrast to the decrease in the CMR of suicide by pesticide among workers from 2011 to 2013, the SMR increased from 65.2 (95% CI: 60.1-70.6) to 78.1 (95% CI: 69.6-87.2). This distinction occurred with more reductions in the general population of workers.

Occupation is one of the social conditions which affects suicide rates.[17-20,25,32] Particular jobs, such as medical professionals, soldiers and veterans, and farmers, showed higher suicidal ideations, attempts, and rates than others.[18] These associations were attributed to job strain, stress, long working hours, and convenient access to suicidal methods.[17]

One advantage of the present study is that the rates and ratios were calculated more accurately than previous studies by using the results of EAPS, surveyed employment and unemployment of the working population taken monthly every year. An analysis by occupation groups in a previous study also find workers in the agricultural, fishery, and forestry industries have more significant suicide rates than workers in other occupational groups.[19,22]

The present study confirms that the A-F-F group was more vulnerable to suicide and suicide by pesticide than others. Even the SMR of A-F-F was higher than one hundred every year, which means that the A-F-F group showed higher suicidality than the general population; the suicide by pesticide decreased, but the overall suicide rate remained dangerously high (488 per 1,000,000 in 2017). Pesticide ban policies achieved a more successful effect on the suicide by pesticide of the A-F-F group than others; however, there was no such decrement in the overall suicide rate of A-F-F.

In addition, the M-P group annually increased both in the CMR and SMR for suicide overall, and the USL group experienced a significant increment through 2011 to 2014, and the SMR of the USL group reached 100 in 2014. The analysis of macroeconomic indicators in the present study implies that UnR affected the increment in the overall suicide rate in 2011 to 2014 because it showed a more substantial value ($\beta_{UnR} = 0.27$) than RGDP and CPI in the second five-year period, 2008-2012.

For comparison between each occupational group, RRs for suicide and suicide by pesticide were calculated through the 15-year period by using SKL as the reference group with age and sex stratification. The A-F-F group showed the highest RR in both suicide overall and suicide by pesticide without stratification, followed by the O-S-T, USL, and M-P groups. The M-P group was riskier than the SKL group for the elderly but less for the young in suicide overall. The young female stratum showed relatively lower RRs than others, which means that the SKL group of the young female group had a higher suicidal risk than other occupations. For suicide by pesticide, the A-F-F group also had the highest RR among occupational groups in all strata; and the old female group showed the most significant RR for A-F-F and the old male group the lowest.

RRs were estimated for each five-year period using the first five-year period as the reference to confirm the effects of time and certain events; the global economic crisis occurred in 2008 and the complete ban of highly toxic pesticides in 2012.[27] RRs for suicide by pesticide experienced dramatic decreases in the second period, and the values halved from the second period to the third period, for almost all occupational groups. This confirms the time trend of suicide by pesticide, and the downward trend became much stiffer after 2013. The overall suicide rate for all workers did not change significantly — meanwhile, rates for the M-P group increased and those for the A-F-F group decreased with time.

The RGDP, UnR, and CPI are major three macroeconomic indicators of a county and are associated with suicide and suicidal behaviors.[23-27,30,34] The present study made regressions to their effects on the suicidality of occupational groups for each period. First, the RGDP did not significantly affect the first and second five-year periods. However, it had a positive association in the third period both in suicide overall and suicide by pesticide. The effects of the RGDP were not consistent in previous studies; there was a weak positive association in men and a weak negative association in women in the general population of Europe from 2001-2011, and the manager-professional and officer-service-trade groups are the only occupational groups with statistically significant positive associations in South Korea.[19,24] The result of the present study

inferred that the effect of the RGDP on suicidality could depend on the time period, not the characteristics of the population.

The UnR showed consistently positive effects for the overall suicide rate without job stratification and with the stratum of workers in the A-F-F group. Meanwhile, the SKL group had a negative association with the UnR in the first five-year period and no significant association in other periods. For suicide by pesticide, the UnR had a negative association in the first and second five-year periods, but no significant association in the last five-year period. In a previous study, the UnR had related the suicide rates only in low social class occupational groups such as unskilled labor and agriculture, forestry, and fishery.[19,27,28] The SKL group has a relatively upper socioeconomic status, so their overall suicide rate would not be sensitive. Suicide by pesticide, which is preferred as a suicidal method in lower-class occupations, showed a positive association with the UnR, but the relationship disappeared in the third five-year period after the number had mainly decreased.[13,14]

The CPI was calculated as the percentage of the rate from one year to another. The means of the CPI are 2.92, 2.98, and 1.24 for each five-year period analyzed in this study. Suicide and suicide by pesticide had a positive association in the first period and a negative association in the third period. If the CPI increased, the household expenditure would increase, and lower socioeconomic class could feel stronger negative effects. The CPI went down under 1.0, so its effects on the lower class would be smaller after 2013, which resulted in a negative association with suicidality.

5. Conclusions

Age, sex, and time period effects and the impact of macroeconomic indicators are different in suicide and suicide by pesticide by occupational groups. The A-F-F group had shown risky conditions concerning suicidality which were even much worse than the general population, and the USL group rapidly worsened in the most recent five-year period. Suicide by pesticide decreased significantly in all occupational groups, but the A-F-F group remained as the highest risk group. The RGDP had a positive association with overall suicide rate in the last five-year period, and the UnR also had a positive association but it disappeared with suicide by pesticide in the third period. The results of this study show that suicidal prevention should be considered for risky occupations in South Korea.

Supplementary Materials: Table S1: Suicidal mortality per 100,000 according to occupational group using direct standardization by five-year age group; Table S2: Standardized Mortality Ratio and 95% Confidence Interval for Men; Table S3: Standardized Mortality Ratio and 95% Confidence Interval for Women.

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