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Statistical Analysis of the Factors of Suicidal Ideation Risk of Korean Elderly:
Using a Panel Logit GLMM

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This study analyzed the effect trend of related factors on the suicidal ideation of the elderly using the 6-year longitudinal data (2012-2017) in the Korea Welfare Panel. To this end, the factors related to elderly suicide were regional, sex and marital status, economic activity, poverty home, elderly welfare, hospital visits, depression, and self-esteem. In order to consider the inherent intrinsic properties of this panel data, we analyzed the random-intercept fixed-effect logit GLMM, where demographic and social factors are fixed-effect variables and other factors are random-effect variables. Based on the results of this study, the importance of a differentiated approach between regional and sex and marital status types was discussed in relation to social welfare interventions to alleviate suicide problems in the elderly. In particular, the effect of sex and marital status on the suicidal ideation risk of the elderly was 2.3 times higher in male living alone than male living with family, while the significant difference in female living alone was not accepted. In addition, the group of male living alone was associated with high depression, low self-esteem, and poor economic factors. Therefore, it is necessary to provide preventive programs for elderly suicide that can increase self-esteem and relieve depression by expanding family tie and social support network for them.

Keywords: Elderly, Suicidal Ideation, Marital Status, Longitudinal Data, GLMM

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I. Introduction

Since the 2000s, Korea's fertility rate has been falling as women's social participation expanded due to rapid economic growth and increased income. On the other hand, with the development of medical technology and the improvement of living standards, the average life expectancy has increased, leading to an aging society. In 1970, the proportion of the elderly aged 65 or older increases from 3.1% to 13.8% in 2017. In 2030, their proportion is expected to increase to 25.0% and become a super-aged society (Statistics Korea, 2019, p.46). In other developed countries, aging has progressed over a long period of time, and the system and support for the welfare of the elderly has been gradually promoted and prepared. However, Korea is rapidly entering an aged society and is unable to respond effectively. Along with this aging phenomenon, the suicide rate of the elderly is relatively high compared to other groups, and it has been raised as a serious problem in society. The suicide rate in Korea reaches a peak from 13.6 (per 100,000 population) in 2000 to 31.2 in 2010. After that, it gradually decreases to 26.6 in 2018. However, in 2018, the suicide rate by age group is 17.6 in the 20s, compared to 32.5 in the 60s, 48.9 in the 70s, and 69.8 in the 80s, showing that the mortality rate of the elderly is 1.9 to 2.8 times higher than the 20s (Statistics Korea, 2019, p.18).

The World Health Organization (WHO) defines suicide as a self-inflicting act that has a fatal effect on one's life. Durkheim (2005, p.4) defined that it is a murder of himself in the form of a direct or indirect death of positive or negative behavior that he or she knows about the consequences that will occur in the future. The American Social Security Act of 1935 stipulated that people aged 65 and over are considered as senior citizens, and that Korea also considers the legal age of senior citizens to be over 65. Therefore, elderly suicide can be defined as self-inflicted acts that lead to the death of an elderly person over the age of 65. Usually, suicidal ideation is a process of suicide, and is an important predictor of suicide attempt.

In other words, the process of suicide is explained by suicide attempt and suicidal behavior, including this suicide ideation. Here, suicidal ideation means that one seriously considers suicide at some point in life, and suicide attempt means deliberately hurting one's life with the intention of dying. And suicidal behavior is defined as the end of life as an act of self-death (Beck, Kovacs & Weissman, 1979, pp.343-345). In particular, since the suicidal ideation of the elderly are actually more likely to result from suicidal behavior than those of younger people, research on elderly suicidal ideation is necessary. Although elderly suicide is an individual problem, it can have a negative effect on society as a whole, so it is not a matter of individual choice, but a social problem, and systematic preventive measures should be taken (Bae, 2011, pp.50-53).

In general, there are three categories of theoretical and empirical backgrounds of existing studies aimed at identifying the causes of suicide among the elderly. First, Freud's (1917, p.243) and Baumeister's (1990, p.91) self-escape theories from the psychological point of view of the suicide individual. When a person deviates between his expectations and reality in life, frustration arises, and this frustration is considered to be incompetent and condemns himself. By constantly comparing oneself with an unattainable goal in this distorted state, one's self-awareness causes painful emotions. The cognitively disintegrating painful emotions attempt to escape from himself, focusing only on specific emotions and actions, resulting in suicide or other destructive actions. In conclusion, they said that human suicide is an action caused by a means of escaping from his suffering (Barzilay & Apter, 2014, p.295). In the human life cycle, elder people experience more stress, and social participation is gradually reduced due to retire from work, spouse's death, physical illness, and economic difficulties. Therefore, McIntosh (1995, p.180) suggested that they fall into mental isolation, helplessness, and despair (depression) and end their lives. Ouellette et al. (2019, pp.1798-1799) reported that the psychological characteristics of individuals, such as psychopathology and susceptibility to stress, play a major role in suicide of the elderly. The National Institute of Mental Health reported that mental

illness, including depression, is an important risk factor for suicide, and more than 90% of suicides are associated with it (Jeon, 2011, p.372).

Second, Durkheim's theory of social integration based on a social structural perspective. He classified the types of suicide, according to the degree to which individuals are controlled and integrated into society. First, if the degree of social integration is low, egoistic suicide increases. In other words, it is the type of suicide that occurs when a person is separated from the community of society and individualized. Second, if the degree of social integration is too strong, altruistic suicide increases. Third, it is an anomic suicide that occurs when society can no longer provide the goals and norms of life necessary for an individual's life in a rapidly changing society. This is a suicide that results from the confusion of individual values (Durkheim, 2005, pp.105-239; An, 2015, p.24). Kim & Kwon (2013, p.239) selected various indicators such as economic development level, poverty rate, welfare expenditure, family integration, and social integration as structural characteristics of Korean society as factors for suicide of the elderly. They suggested that Korea's lower level of social integration has had a significant impact on suicide by lack of adequate protection and care for the elderly in need of care.

Third, it is the ecological system theory of Bronfenbrenner (1977) and Kemp (1998). This theory focuses on the suicide of the elderly, not just on the personal characteristics of the elderly, but on the interactions between the various environmental systems to which they belong. Ecosystem theory is a theory in which Bronfenbrenner(1977, pp.513-518) combines ecological perspectives with Bertalanffy's (1968, pp.30-38) general system theory to analyze and explain human development. Afterwards, this theory supplemented the existing theory of welfare based on simple clinical practice by providing a broad social context for social welfare practice by adding an ecological system perspective to Gitterman & Germain's (2008) life model of social work practice (Hong, 2017, p.58). In reality, suicide in the elderly is caused by a combination of factors such as economic poverty, health, stress, family relations, and social system. Therefore, the suicide problem of

the elderly is to consider the interaction between the individual and the environment together rather than to grasp the partial relationship between several factors (Blow et al., 2004; Doh & Hoe, 2015, p.45). Bae (2005, pp.15-22) suggested that the approach of an ecological system that considers not only the personal characteristics of the elderly as an actor, but also the environmental impacts from his family and community, will be a useful analytical tool for elderly suicide research.

It is difficult to understand the suicide of the elderly by region because most of the previous studies related to suicide of the elderly mentioned above are the results of the analysis of one specific region or the whole country. This is because, according to Durkheim's social integration theory and Bronfenbrenner's ecological system theory, the elderly suicide risk may differ between regions. It is also a cross-sectional analysis using cross-sectional data investigated at a specific point in time. Of course, it is important to identify factors affecting the risk of suicide at a specific point in time through cross-sectional analysis, but it is also necessary to identify structural factors of suicide that are continuously fluctuating over a long period of time. Recently, studies have been conducted on longitudinal data analysis using linear mixed models (LMM) and generalized linear mixed models (GLMM) to estimate the dynamic change of factors related to elderly suicide.

Lee & Lee (2016, p.277) analyzed the dynamic effects of material deficiencies experienced by the elderly on mental health (depression, self-esteem, and suicidal ideation) by applying the panel logistic GEE (generalized estimating equations) model using data from the 7-year Korean Welfare Panel (2007-2013). Shin & Lee (2016, p.1) analyzed the duration of suicidal ideation, suicidal plans, and suicidal behavior after the retirement of the elderly and the risk probability for each period by survival analysis. As a result of the analysis, the risk of suicide among the elderly is generally the highest within one year after retirement, and the probability of suicide risk by each age tends to be somewhat dispersed by year. Lee (2017, p.191) classified the elderly into poverty and non-poverty groups and estimated the dynamic effects of factors on suicidal ideation. As a result of analysis, in the poverty group,

factors affecting elderly suicidal ideation are public welfare, participation in economic activities, annual income, and house ownership, whereas in the non-poverty group, chronic diseases, physical health factors, and marital status. However, psychological factors such as depression and self-esteem are important variables of suicidal ideation regardless of poverty.

The above-mentioned studies that dynamically estimated the effects of factors on elderly suicide did not include fixed effect variables such as regions, periods, and sex and marital status in the model, which indicate the intrinsic specificity of each unobserved individual. Therefore, because the model does not contain the correlation that may exist between the covariates and the error term, the estimated coefficients are inconsistent and can be biased estimates. In addition, it is desirable to reduce the variance of the model by introducing a time-varying random effect variable because there are often parts in the longitudinal data that cannot explain the inherent specificity of each individual as fixed effect variables.

This study used data from the six-year Korean Welfare Panel (2012-2017) surveyed by the Korea Institute for Health and Social Affairs (KIHSA). Variables are selected as independent variables for income, smoking, hospital visits, economic activity, depression, self-esteem, home poverty, and elderly welfare, which are identified in previous studies as factors influencing elderly suicide. Then, in order to estimate the regression coefficient with high confidence in the covariates, a panel logit GLMM with regional, year, sex and marital status as control variables is formed, and the dynamic effects of these factors on elderly suicide are estimated. In this study, the suicide risk rate as a dependent variable is made with or without suicidal ideation (yes or no).

Ⅱ. Research Methods

1. Participants

The data used in this study was the Korea Welfare Panel Survey (KOWEPS). This data has been jointly surveyed by the Korea Institute for Health and Social Affairs and the Social Welfare Research Institute of Seoul National University for 14,463 people in 7,072 households since 2006, and has been released until the 12th survey data (2017) as of 2019. The purpose of this survey was to provide basic data for establishing various welfare policies by dynamically grasping the living conditions and social welfare needs of population groups by class and age in a rapidly changing environment. The subjects of this study were 2,380 people who responded to suicidal thoughts until 2017 as an elderly person over the age of 65 as of 2012. This KOWEPS data has national representativeness as a longitudinal survey with a large sample size for the whole country. In addition, it is suitable for research on health and welfare for low-income people by allocating about 50% of the total sample to low-income people with a median income of less than 60%. The question item about suicidal ideation was newly added since 2011. However, starting in 2012, the survey began by setting a clear temporal category of 'over the past year' based on the survey date. Therefore, we used data from 2012 to 2017, and we followed KOWEPS' User's Guide for question items constituting each variable, calculating the value of variables, combining data by year, and merging data for households and household members.

2. Measures

<Table 1> shows the dependent and independent variables used in this study. The dependent variable was whether the elderly think suicide. Based on the current survey date, it was a binary variable that had a value of 1 if it had experienced

suicidal ideation and had a value of 0 otherwise. The relationship between thinking of suicide and the factors affecting it from a dynamic point of view can be defined as the hazard ratio of Cox that considers whether or not to think of suicide and the time it takes to suicidal ideation. Therefore, during the analysis period, the cutoff data are reflected in the analysis because many of the elderly people in the study may end the analysis period without thinking about suicide.

As for the independent variable, the following 8 significant variables were selected by the stepwise method in the multiple regression model for 15 variables selected by referring to previous studies. The demographic and social factors were regions, years, sex and marital status, and economic factors were annual household income, economic activities, poverty home, and elderly welfare. The physical health factors were smoking and hospital visits, and the psychological factors were the level of depression and self-esteem. Here, the depressive level was the sum value for responding to the 4-point Likert scale for 11 depressive questions (range 0~33

Table 1. Definition and properties of variables

	variables	categories
dependent variable	suicide risk	suicidal ideation: no=0, yes=1
time-invariant covariates	regions	Seoul=1, Gyeonggi=2, Gyeongnam=3, Gyeongbuk=4, Chung-nam=5, Gangwon&Chungbk=6, Jeonnambuk=7
	years	2012=1, 2013=2, 2014=3, 2015=4, 2016=5, 2017=6
	sex and marital status	male living with family(MF), male living alone(MA), female living with family(FF), female living alone(FA)
time-varying covariates	income	household income: 10,000 won/year(continuous variable)
	smoking	cigarettes/day(continuous variable)
	hospital visits	hospital visits No/year(continuous variable)
	economic activity	economic activity=1, non-economic activity=0
	depression	very rare=1, sometimes=2, often=3, mostly=4 (Likert scale)
	self-esteem	very rare=1, sometimes=2, often=3, mostly=4 (Likert scale)
	poverty home	experiencing poverty at home, No/year(continuous variable)
	elderly welfare	use of social welfare services, No/year(continuous variable)

points). Therefore, the higher the depression level, the greater the depression. Self-esteem was the average value for responding to a 4-point Likert scale for ten questions that indicate the degree of self-esteem in the elderly (range 0~3 points). Therefore, the higher the self-esteem value, the higher the self- esteem.

3. Statistical model

In this study, frequency analysis was conducted on suicide risk, demographic characteristics, economic factors, and psychological factors of the elderly aged 65 years or older, and the trend of suicidal ideation by year was analyzed. In addition, in order to estimate the effects of factors on suicidal ideation of the elderly, it was analyzed using a generalized linear mixed model (GLMM) for longitudinal binary data (Breslow & Clayton, 1993).

GLMM consists of the following four components. First, it is the distribution of response values under a given random effect (this study assumes a logistic distribution). Second, it is a linear predictor that implies parametric and random effects. Third, there is a link function that connects the conditional mean and linear estimate of the response values. Finally, it is a distribution of random effects (usually assumes a normal distribution).

GLMM is particularly effective for the longitudinal analysis of data obtained in the form of a group from categorical data, as in the case of this study. For example, if y_{ij} is a binary number representing the suicidal ideation (yes=1 or no=0) at the jth time point ($j = 1,...,T$) of the i-th old man, the response variable (y_{ij}) is defined as follows:

$$(1) \quad y_{ij}|b_i \sim Bernoulli(b_i);\ \log it(b_i) = x_{ij}^{'}\beta + b_i,$$

where x_{ij} is a $p \times 1$ covariate vector corresponding to y_{ij}, and b_{ij} is a random effect vector. This is expressed as a special linear mixed model

(2) $$y_{ij} = \beta_0 + \beta_1 x_{ij1} + ... + \beta_p x_{ijp} + b_i + \epsilon_{ij}.$$

The expression (2) is extended to to the logistic model for longitudinal binary data and is expressed as follows:

(3) $$y_{ij}|b_i, x_i \sim ind\ \ Binomial[1, \pi_{ij}^b(x_i)]$$
$$\log it[\pi_{ij}^b(x_i)] = \log[\frac{\pi_{ij}^b(x_i)}{1-\pi_{ij}^b(x_i)}] = \beta_0 + \beta_1 x_{ij1} + ... + \beta_p x_{ijp} + b_i,$$

where b_i is the normal subject-specific random effects, and σ_b^2 is between-subject variation. If $\sigma_b^2 = 0$, there is no correlation between subjects, and if σ_b^2 increases, the correlation between subjects increases. Since the probability of success (π_{ij}^b) is subject-specific, parameters β have subject-specific interpretation.

In this analysis, using PROC GLIMMIX in SAS (version 9.4), the elderly suicide risk level of the fixed effect variables was estimated and tested by LS-Mean, and the effects of the covariates were estimated by three panel logit GLMM models. For more information on the estimation of this GLMM, see Zhang (2019, pp.172-184); McCulloch (1997, pp. 163-166); Breslow & Clayton (1993, pp. 10-13).

Ⅲ. Results

<Table 2> shows the sample composition by sex, region, and marital status of the elderly aged 65 years or older. The total sample size was 2,380. By sex, female accounted for 44.1% and male 55.9%, indicating a higher percentage of male. The composition of the seven regions was Seoul 11.6%, Gyeonggi 16.4, Gyeongnam 18.4, Gyeongbuk 15.7, Chungnam 9.0, Gangwon& Chungbuk 8.3, and Jeonnambuk 20.6, respectively. The composition by sex and marital status was 49.2% for male

living with family (MF), 6.7 for male living alone (MA), 1.3 for female living with family (FF), and 42.8 for female living alone (FA). Older males lived mostly together, while older females lived mostly alone.

<Table 3> shows the trend of suicide risk by year and region for study subjects. By region, the average 6-year suicide risk was highest in Chungnam with 7.4%. Gyeonggi, Gyeongbuk and Seoul were at a moderate level with 4.1-4.8%, while Jeonnambuk, Gangwon&Chungbuk, and Gyeongnam were relatively low with 3.3-3.7%. By year, it showed a tendency to increase until the first 3 years, but a tendency to decrease from the 4th year, and the last year showed a lower suicide risk level (1.5-4.0%) in most regions except Chungnam. The deviation of suicide risk for each region was small, 2.0 to 5.8% in Jeonnambuk and Seoul, while Gyeongnam and Chungnam regions were relatively large at 1.6 to 9.8%.

Looking at the risk of suicide by sex and marital status in Table 4, 3.4% of males thought suicide, and 5.3% of females thought suicide. The difference in the risk of suicide among the elderly was very large according to the marital status of the elderly. The risk of suicide in MF was 2.7%, compared to 8.5% in MA. The risk of suicide in MA was about 3.1 times higher than that in MF. On the other hand, the risk of suicide was 7.8% in FF and 5.3% in FA. In females, living alone was about 47% less than living with family. In Table 5, FF's experiences in family poverty and participation in economic activities were 30% less and 41.7% more than those of FA. It is inferred that such a psychological responsibility to support the FF's family increased their risk of suicidal ideation.

Table 2. Characteristics of sample

(unit: persons(%))

sample No	gender		region				
	male	female	Seoul	Gyeonggi	Gyeongnam	Gyeongbuk	Chungnam
2,380	1,331(55.9)	1,049(44.1)	276(11.6)	390(16.4)	439(18.4)	373(15.7)	215(9.0)

		sex-marital status			
GChungbuk	Jeonnambuk	MF	MA	FF	FA
198(8.3)	489(20.6)	1,170(49.2)	161(6.7)	30(1.3)	1,019(42.8)

Table 3. Trends in suicide risk among the elderly by region and year

(unit: rate)

	2012	2013	2014	2015	2016	2017	Mean
Seoul	0.0476	0.0473	0.0580	0.0474	0.0580	0.0290	0.0479
Gyeonggi	0.0462	0.0545	0.0567	0.0417	0.0181	0.0282	0.0409
Gyeongnam	0.0162	0.0275	0.0874	0.0370	0.0323	0.0205	0.0368
Gyeongbuk	0.0485	0.0515	0.0678	0.0191	0.0380	0.0402	0.0442
Chungnam	0.0654	0.0849	0.0714	0.0845	0.0427	0.0977	0.0744
GChungbuk	0.0203	0.0508	0.0505	0.0367	0.0412	0.0152	0.0358
Jeonnambuk	0.0265	0.0412	0.0455	0.0373	0.0291	0.0204	0.0333
Mean	0.0368	0.0479	0.0627	0.0405	0.0349	0.0324	0.0425

Table 4. Trends in suicide risk rate among the elderly by sex and marital status

	2012	2013	2014	2015	2016	2017	Mean
male	0.0318	0.0388	0.0510	0.0283	0.0268	0.0270	0.0340
female	0.0429	0.0593	0.0775	0.0557	0.0451	0.0391	0.0533
male-family(MF)	0.0250	0.0278	0.0381	0.0218	0.0244	0.0248	0.0270
male-alone(MA)	0.0808	0.1188	0.1438	0.0760	0.0440	0.0435	0.0845
female-family(FF)	0.0333	0.1000	0.2000	0.0667	0.0333	0.0333	0.0778
female-alone(FA)	0.0432	0.0581	0.0739	0.0553	0.0455	0.0393	0.0526

Table 5. Comparison of covariate characteristics[1)]

	income	economic activity	poverty home	elderly welfare	smoking	hospital visits	depression	self esteem
male	2371.3	0.48	0.07	2.02	2.77	24.97	8.18	1.60
female	1148.8	0.24	0.10	2.62	0.51	42.95	10.34	1.40
MF	2495.8	0.50	0.05	1.95	2.53	24.98	7.98	1.62
MA	1465.1	0.32	0.22	2.53	4.53	24.04	9.60	1.46
FF	1423.4	0.34	0.07	2.33	0.46	42.81	10.12	1.43
FA	1140.7	0.24	0.10	2.63	0.52	42.96	10.35	1.40
Chungnam	1917.2	0.46	0.07	2.55	2.06	38.02	9.80	1.54
year3 (2014)	1724.6	0.40	0.09	2.34	2.02	34.65	9.26	1.50
year5 (2016)	2026.9	0.35	0.07	2.40	1.48	32.74	9.26	1.50
total mean	1832.2	0.38	0.08	2.29	1.77	32.84	9.13	1.51

1) Refer to Table 1 for the units of variables in the table.

<Table 5> shows the characteristics of covariates by sex and marital status. By sex, male's average household income, smoking amount, participation in economic activities, and self-esteem were higher than those of the female, whereas female's hospital visits, depression, elderly welfare experiences, and poverty home experiences were higher than those of male. By marital status, living with family had a higher average household income, participation in economic activities, and self-esteem than those of living alone, while living alone had a higher elderly welfare experience, poverty home experiences, smoking amount, and depression than living with family.

In this study, longitudinal data were used to analyze the factors affecting suicide risk in the elderly using a panel logit GLMM (Zhang, 2019, pp.172-204). The first model was the Pooled OLS regression model. This model assumed that the variance of b_i, which represented the intrinsic specificity of each subject, which was not observed in the previous equation (3), is zero. That is, it was assumed that the suicide risk rate of the elderly, a dependent variable (Y), could be fully explained by the observed data on the covariates (X) introduced in the model. The problem with this model is that it does not distinguish fixed effects such as region, sex and

marital status, so it is not possible to tell whether the effects of covariates on suicide risk over time are the same for each region or sex and marital status. As a result, since the error term can be correlated with some of the covariates included in the model, the estimated regression coefficients are inconsistent and bias estimates. The second model was a three-factor panel logit fixed effect model. This model was a model that introduces a fixed effect variable that classifies groups by region, year, and sex and marital status type, which indicated the inherent characteristics of each entity in the first model. Here, it is assumed that b is related to the covariate (X), and it is assumed that each entity has a unique constant term. That is, it is assumed that the intercept of b is time-invariant, but different for each entity, and the slope is time-invariant and the same between entities. The third model was a panel logit GLMM model that introduced random effects to the second model. Here, the random effect refers to the variance that cannot be described as a fixed effect variable, and the random effect is composed of within-group and between-group. Here, within-group variance means variance caused by the inherent characteristics of each individual, and between-group variance means variance that is common among individuals. In this model, the introduction of covariates such as depression, etc. as time-varying variables can reduce the variance of the model generated within the group and increase the fixed effect. In this model, b is a part of the error term that can have a random value for each individual. Therefore, since there is a correlation between different error terms for different periods, it should be estimated as GLS instead of OLS. Table 7 shows statistics of -2log L, AIC, and BIC for the fitness test of three models. These values of the third model were 3819.81, 3867.81, and 4005.40, which were smaller than those of the first and the second model. Therefore, it was confirmed that the third model had the highest fitting power in analyzing this data.

In this panel logit GLMM model, the risk of elderly suicide as a dependent variable corresponding to the region, year, and sex and marital status types, which are time-invariant fixed-effect variables, was estimated by LS-Means. And the differences

between the groups of these variables were tested for type-III test and graphics for LS-Mean pairwise comparison. This is because the arithmetic mean of one group does not reflect other effects because the observed data of each of these three factors is different from each other. According to the results of Type III F-test, null hypotheses that suicide risk rates were the same between years, regions, and sex and marital status levels were rejected at α<.01, respectively.

<Table 6> and [Figure 1] show the results of the pairwise comparison to test whether the responses of suicide risk (LS-Mean) are the same for each group of these three fixed effect variables. When looking at the risk of suicide by region, Chungnam and Gyeongbuk were the highest with 13.5% and 7.2%, and the other regions ranged from 3.8% to 5.9%. As a result of the pairwise comparison test at $\alpha = 0.05$, whether there is a difference between LS-Mean estimates between regions, Chungnam accepted the difference in all other regions, and the differences were also accepted between Gyeongbuk and Gyeongnam. However, differences in LS-Means among other regions were not accepted. In addition, ANOM (analysis of means) was performed to test the differences between the LS-means at each group level and the LS-means of the entire group. As a result of the ANOM test of 7 regions at α=0.05, there was a positive difference in Chungnam and a negative difference in Gyeongnam for the LS-means of the entire region. There was no difference in other regions. Therefore, Chungnam was the region with high LS-mean for suicide risk, Gyeongnam was the low region, and the other regions were the middle regions. In particular, the high risk of suicide in Chungnam was attributed to the fact that smoking was 16.4%, hospital visits 15.8%, and depression was 7.3% higher than those in all regions (Table 5).

In Table 6, the risk of suicide by year was the highest at 9.3% and 11.2% for the 2nd and 3rd years (2013 and 2014), and the other years range from 3.9 to 5.8%. As a result of the pairwise comparison test for each year, the 3rd year was accepted as a difference with all years except the 2nd year, and the 2nd year was accepted as the difference with all years except the 3rd year. However, no significant

differences were accepted between other years. As a result of the ANOM test for each year, positive differences were accepted in the 2nd and 3rd years, and negative differences were accepted in the 5th and 6th years. Therefore, the 2nd and 3rd years were the years with high risk of suicide, the 1st and 4th years were the middle years, and the 5th and 6th years were low years.

The suicide risk by sex and marital status type was in the order of 9.2% for MA, 8.3% for FF, 5.6% for FA, and 2.8% for MF. As a result of the pairwise comparison test for each of these four types, MF was different from MA, FF, and FA, and MA and FA were also different. However, the differences between FF and FA, and MA and FF were not accepted. As a result of the ANOM test of these four types, positive differences were accepted in MA, FF, and FA, and negative differences were accepted in MF. Therefore, it was confirmed that MF was a group with lower suicide risk. However, because the sample size of FF was small, the confidence interval of FF was large in ANOM test (Figure 1).

Table 6. Least squares means for 3 fixed covariate[1)]

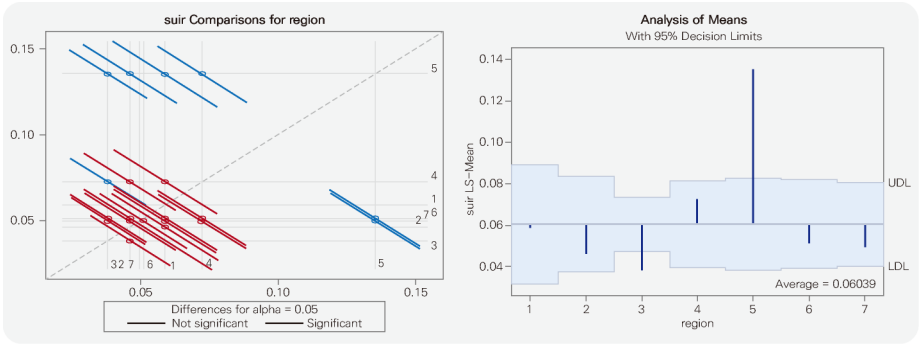
	year							
	2012	2013	2014	2015	2016	2017	Seoul	Gyeonggi
estimate	0.04585	0.09257	0.11160	0.05754	0.03852	0.04148	0.05901	0.04635
SE	0.01097	0.01097	0.01097	0.01098	0.01098	0.01098	0.01519	0.01240
t-value	4.18	8.44	10.17	5.24	3.51	3.78	3.88	3.74
Pr > |t|	<.0001	<.0001	<.0001	<.0001	0.0005	0.0002	0.0001	0.0002

region					sex-marital status			
Gyeongnam	Gyeongbuk	Chungnam	GChungbuk	Jeonnambuk	MF	MA	FF	FA
0.03830	0.07242	0.13510	0.05131	0.04963	0.02818	0.09160	0.08267	0.05592
0.00789	0.01144	0.01206	0.01165	0.01115	0.00247	0.00680	0.01615	0.00278
4.85	6.33	11.20	4.40	4.45	11.40	13.46	5.12	20.10
<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001

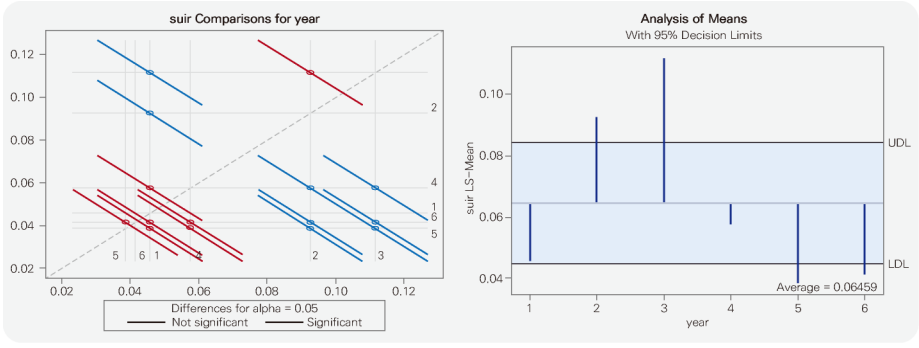
1) Type III tests results (F-value(p>F): Year(7.65(<.0001)), Region(8.36(<.0001)), sex-mstatus(37.96(<.0001))

Figure 1. LS-means plot of pairwise differences and ANOM plot LS-means difference for 3 fixed covariates

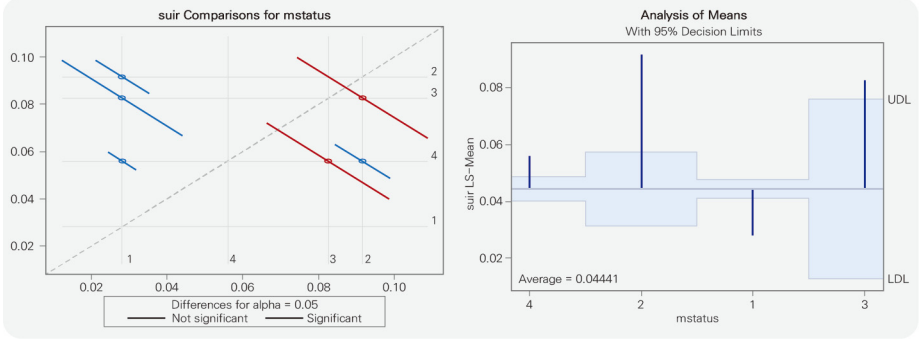
(1) region



(2) year



(3) sex and mstatus



The estimation results of the third model are presented in the third column on the right of Table 7. In the model, the fixed effects of time-invariant variables such as region, year, and sex and marital status were estimated with the lowest level as a reference. That is, assuming that all covariate variables except the regional variable in the model are fixed, if an elderly person moves from the reference area (Jeonnambuk) to Seoul and Chungnam, the OR of suicide risk increases by 97.8% and 172%, respectively. However, Gyeongnam did not accept statistical differences.

The fixed effect for each year was estimated using the 6th year as the reference year. The 5th year did not reject the null hypothesis (which is equivalent to the suicide risk effect of the 6th year), but it was rejected in other years. That is, under the assumption that all covariate variables except the year variable in the model are fixed, if an elderly person moves from the 6th year to the 1st and 3rd year, the OR of suicide risk increases by 25.6% and 120%, respectively. In summary, the OR of suicide risk by year increased up to the 3rd year, but decreased significantly from the 4th year. As such, it is inferred that the decrease in the effects of suicide risk for the elderly over the years was the result of an improvement in family poverty due to an increase in income and a decrease in the amount of smoking and the number of hospital visits as indicators of physical health (Table 5).

The fixed effect by sex and marital status was estimated using MF as a reference. The FA did not reject the null hypothesis (which is equivalent to MA's suicide risk effect), but the FF and MA rejected the null hypothesis, respectively. In other words, assuming that all covariate variables except the sex and marital status are fixed in the model, if one elderly person moves from MF to MA and FF, the OR of suicide risk increased by about 110% and 106%, respectively. Therefore, it was suggested that MF and FA were groups with relatively low suicide effects, while MA and FF were groups with high suicide effects. Since the sample size of FF was small, the effect of the estimated regression coefficient of FF was not significant at $\alpha = 0.05$, but its effect was significant at $\alpha = 0.1$ (Table 7).

Table 7. Factor effect analysis of elderly suicide ideation risk(panel-logit GLMM)

	Pooled OLS		Fixed Effect		Fixed+Random Effect[1)]		
	estimate	S.E.	estimate	S.E.	estimate	S.E.	OR (95% CI)
intercept	-5.094***	0.2311	-6.002***	0.2983	-6.654***	0.3536	
year1 (2012)			0.190	0.1750	0.228	0.1845	1.256 (0.874-1.803)
year2 (2013)			0.432**	0.1649	0.484***	0.1734	1.622 (1.155-2.279)
year3 (2014)			0.715***	0.1564	0.789***	0.1639	2.202 (1.597-3.036)
year4 (2015)			0.223	0.1691	0.222	0.1772	1.248 (0.882-1.767)
year5 (2016)			0.041	0.1715	0.044	0.1808	1.045 (0.733-1.489)
year6 (2017)			0	.	0	.	1.000.
Seoul			0.639***	0.1711	0.682**	0.2113	1.978 (1.307-2.993)
Gyeonggi			0.445**	0.1620	0.489*	0.1963	1.631 (1.110-2.396)
Gyeongnam			0.347*	0.1584	0.387*	0.1904	1.472 (1.013-2.138)
Gyeongbuk			0.598***	0.1584	0.638***	0.1924	1.892 (1.298-2.759)
Chungnam			0.934***	0.1629	0.999***	0.2045	2.715 (1.819-4.054)
GChungbuk			0.554**	0.2023	0.568+	0.2437	1.764 (1.094-2.844)
Jeonnambuk			0	.	0	.	1.000
FA			0.177	0.1166	0.149	0.1389	1.160 (0.884-1.523)
MA			0.696***	0.1493	0.742***	0.1916	2.101 (1.443-3.058)
FF			0.701*	0.3043	0.723+	0.3963	2.060 (0.947-4.480)
MF			0	.	0	.	1.000
income	-0.00006	0.00004	-0.00006	0.00005	-0.00005	0.00005	1.000 (1.000-1.000)
smoking	0.039***	0.0073	0.028***	0.0078	0.033***	0.0093	1.034 (1.015-1.053)
hospitalV	0.001	0.0010	0.002*	0.0010	0.003*	0.0011	1.003 (1.000-1.005)
economicA	-0.242*	0.1114	-0.294*	0.1145	-0.315*	0.1289	0.730 (0.567-0.940)
depression	0.217***	0.0101	0.222***	0.0105	0.235***	0.0122	1.265 (1.235-1.296)
self-esteem	-0.491***	0.0890	-0.531***	0.0919	-0.561***	0.1015	0.571 (0.468-0.696)
homeP	0.407***	0.0679	0.355***	0.0695	0.380***	0.0812	1.462 (1.247-1.714)
elderlyW	0.070*	0.0339	0.082*	0.0357	0.081+	0.0417	1.084 (0.999-1.177)
-2log L	4028.03		3931.79		3868.41		
AIC	4046.03		3977.79		3916.41		
BIC	4113.97		4151.43		4055.01		
Peason χ^2	11354.62 (p=0.81)		11421.12 (p=0.81)		7199.82 (p=0.51)		

1) $\sigma_{\hat{b}}^2 = 1.0473$

+: p<0.1; *: p<0.05; **: p<0.01; ***: p<0.001

<Table 7> shows the results of estimating the effects of suicide risk in the elderly for eight time-varying covariates. Among the effects of these variables on suicide risk, household income did not reject null hypothesis ($H_0 : \hat{\beta}_k = 0$), so its significance was not accepted. On the other hand, the elderly welfare experience the number of hospital visits was accepted at α=0.1, the participation in economic activities and the number of hospital visits were accepted at α=0.05, and the amount of smoking, depression, self-esteem and poverty home were accepted at α=0.001. In other words, assuming that all other variables were fixed except for the economic activity participation variable, the OR of suicide risk among the elderly people participating in economic activity decreased by 27% for the elderly who did not participate in the economic activity. In summary, participation in economic activities was a factor that reduced the suicide risk of the elderly, and poverty home and elderly welfare experience were factors that increased the suicide risk of the elderly.

Among the physical health factors, assuming that all covariates except for the smoking variable were fixed, if the amount of smoking increased by 1 cigarette/ day, the OR of the suicide risk of the elderly increased 3.4%. Also, the OR of suicide risk in the number of hospital visits increased by about 0.3%. Therefore, the amount of smoking and the number of hospital visits were factors that increased suicide risk among the elderly. Among the psychological factors, assuming that all covariates except for the depression variable were fixed, if the depression increased by 1 score, the OR of suicide risk increased by 26.5%. On the other hand, the OR of suicidal risk of self-esteem decreased by 42.9%. Therefore, depression was a factor that increased suicide in the elderly and self-esteem was a factor that decreased it.

Ⅳ. Discussion and Conclusion

This study estimated the effects of related factors on the suicidal ideation of the elderly with the panel logit GLMM model using the 6-year (2012-2017) longitudinal data of the Korean Welfare Panel. To this end, the model variables were selected by region, year, sex and marital status, household income, participation in economic activities, poverty home, elderly welfare experience, smoking, hospital visits, depression level, and self-esteem. In order to consider the inherent intrinsic properties of the panel data, the demographic social factors (region, year, sex and marital status) were considered as fixed effect variables and the model was controlled. In addition, to consider the random effects that may appear in the longitudinal analysis, other factors were considered as random effect variables and analyzed by the random intercept fixed effect logit GLMM that can be mutually controlled.

The validity of selecting demographic social factors as a fixed-effect variable of the model was tested by LS-means. As a result of the ANOVA test of the fixed effects of these factors, the null hypothesis that the risk of suicide was the same between these factor levels was rejected at a high significance level. Therefore, the validity of including them in the model was confirmed. As a result of testing ANOM for the difference in suicide risk among the regions, positive differences were accepted in Chungnam and negative differences in Gyeongnam. By year, positive differences were accepted for the 2nd and 3rd years, and negative differences were accepted for the 5th and 6th years. In sex and marital status types, positive differences were accepted for MA, FF, and FA, but negative differences were accepted for MF.

In this model, the effects of sex and marital status on the suicide risk of the elderly were estimated using MF as a reference. The null hypothesis that the effect of FA is the same as that of MF was not rejected, but null hypotheses were rejected by FF for α=0.1 and MA for α=0.001. In the model, under the assumption that other independent variables are fixed except for this variable, the effect of sex and marital status on the risk of suicide in the elderly increases for MA and FF compared to

MF. In other words, the effects on their suicide risk were high in MA and FF, and low in MF and FA. These results are consistent with the results of previous studies that spouse and families living together is an important factor for suicide of the elderly (Choi et al., 2014; Cho, 2019; Yang & Moon, 2020). This is because the elderly living alone have neglected physical health care and are not economically prepared for old age, so they lack the physical and mental resources and mechanisms to cope when they face a life crisis (Sohn, 2012, P.123). Kim (2009, pp.336-340) reported that MA has a higher risk of stress perception, depression, and suicidal thought compared to MF, while FA has a lower risk of stress than FF. Lee (2005, pp.158-161) reported that female elderly have less negative experiences and better adapt to reality after divorce or companion death than male elderly. And Coombs (1991, p.100) argued that FA elderly develop better relationships with close people such as family and friends than MA elderly.

<Table 7> shows the results of estimating the effect of the selected time-varying variables on the risk of suicide in the elderly, to reduce the variance caused by the variation of random effects in the model. First, in terms of economic participation activity, the suicide effect of the elderly who participated in economic activities was lower than that of the elderly who did not participate. On the other hand, as the experience of family poverty and welfare for the elderly increased, the elderly suicide increased. According to Lee (2017, p.211), the rate of suicidal ideation among the poor elderly is 6.22%, which is 2.2 times higher than the 2.79% of the ordinary elderly. More specifically, the experience of suicidal ideation of the elderly receiving public welfare is about 1.3 times higher than that of the non-receiving elderly, and the elderly who are engaged in economic activities such as self-employment are 0.6 times lower than the unemployed elderly. The number of elderly welfare experiences that has a positive effect on the suicide rate of the elderly may be because the majority of the recipients of the welfare of the elderly themselves are economically poor. These results imply that the economic condition must be stabilized during the elderly to prevent mental health problems such as suicidal ideation. Therefore,

measures such as income support and job creation are needed to solve the poverty problem of the elderly.

In terms of physical health factors, the amount of smoking and the number of hospital treatments significantly increased the suicidal ideation risk for the elderly. According to Choi et al. (2015, p.463, p.465), the OR of the suicidal ideation risk was significantly increased to 1.6 times in the elderly who smoked compared to the non-smoking elderly. However, in the results analyzed by sex, smoking is not a significant factor in suicidal ideation risk in male elderly, but is reported to be a significant factor in female elderly. Conwell et al. (2002, p.195) stated that physical health has a direct effect on suicide in old age. Kim (2002, p.168) confirmed that the effect of physical health status of the elderly on suicidal ideation is mediated by depression. This weakening of the physical vitality and health of the elderly may be a factor that increases psychological atrophy and deteriorates the quality of life, causing depression, thereby increasing the risk of suicide in old age. Therefore, it is necessary to monitor the elderly suffering from physical illnesses to see if they are experiencing depression, and to screen and manage them to prevent suicide. In particular, since chronic diseases are known to be an important factor in elderly suicide in old age, studies on elderly suicidal ideation risk factors for chronically ill patients should be conducted in the future.

In psychological factors, depression significantly increased the risk of suicide in the elderly, while self-esteem significantly decreased it. In this study, the results that depression significantly affect suicidal ideation risk in the elderly are consistent with many previous studies (Szanto et al., 2001; Chan et al., 2011). The results of self-esteem directly affecting suicidal ideation are consistent with the studies of Hwang & Kim (2008, pp.397-398) and Hong (2017, p.65). In addition, it is indirectly the same as the research results of Park (2008, p.982) and Bae (2011, pp.50-53) that self-esteem has a moderating effect between depression and suicidal ideation. In particular, Sohn (2012, pp.121-122) and Hong (2017, p.65) reported that males living alone have higher levels of depression and suicidal ideation risk,

consistent with the results of this study. Therefore, the elderly group of male living alone who are at greater risk of suicide should have a separate program to expand their family ties and social support network to increase their self-esteem and reduce their depression.

The implications of the results of analyzing the effects of factors on suicidal ideation risk among Korean elderly with this panel logit GLMM are as follows. First, in order to estimate highly reliable effects of factors affecting suicidal ideation risk by using longitudinal data on related factors affecting suicidal ideation in the elderly, the model was controlled by including unobserved regions, years, and sex and marital status factors as fixed effect variables. In addition, by introducing time-varying covariate factors representing the random effects that may appear in the longitudinal analysis, the model's goodness of fit was improved by estimating using the random-intercept fixed effect GLMM model that mutually controlled them.

Second, the suicidal ideation risks by sex and marital status type were in the order of MA> FF> FA> MF. As a result of the analysis, compared with the effects of sex and marital status on suicidal ideation risk in the elderly in MF, 2.3 times in MA and 2.2 times in FF were significantly higher. These results suggest that the suicidal ideation risk analysis of the elderly should be estimated not only by sex, but also by marital status type, and that it is more efficient to establish suicide prevention measures according to these types.

Third, among the covariates in the model, economic activity and self-esteem had a negatively significant effect on suicidal ideation risk in the elderly, and poverty home, elderly welfare, smoking, hospital visits, and depression had a positive significant effect on it. In the type of marital status, the effects of depression and self-esteem on the suicidal ideation risk were highly significant differences between MF and MA, but not significant differences between FF and FA. In addition to the high depression and low self-esteem of MA, they were also in poor economic condition with low household income and low participation in economic activities. Therefore, it is necessary to expand family ties and social support network for them

to take measures to increase their self-esteem and relieve their depression. And they should also be provided with programs to ensure income and participate in social activities. On the other hand, the number of elderly welfare experiences of FF was lower than that of FA, and the level of depression was significantly higher in female than male, and their economic and physical health factors were also poor. Therefore, in elderly female, it would be desirable to take preventive measures considering the FF group responsible for the family's livelihood and their depression, poverty, and health.

This study estimated the regression coefficients using a panel logit GLMM with longitudinal data on factors related to suicidal ideation risk among the elderly in Korea, so that it was possible to control unobserved heterogeneous characteristics of the elderly in the sample unlike the previous studies. Therefore, it is meaningful to improve the accuracy and reliability of the estimates of factors for the suicidal ideation risk rate of the elderly by reducing biases of the estimated coefficients and ensuring asymptotic consistency.

However, as shown in this study, the dynamic causal relationship between suicidal ideation risk rate and affecting factors in the elderly has to be limited in presenting effective suicide prevention measures for the elderly. In order to present effective measures to prevent suicide in the elderly, it is necessary to know not only the dynamic causal relationship of factors, but also the times when the elderly think suicide and the risk probability of each occurrence. In addition, it is desirable to identify factors affecting suicidal ideation risk significantly for each time, and to estimate the coefficients of the model for each sex and marital status type. This is because there is a statistically significant difference as a result of testing the effects of sex and marital status on the suicidal ideation risk rate of the elderly. However, since the number of samples of FF in this data was small, it was limited to estimate as GLMM, so it was used only as a control variable. Therefore, the next study should conduct a survival analysis using the Cox proportional hazards model, and also expands the number of samples in the FF group to estimate the model for each

sex and marital status type.

이종형은 미국 University of Illinois-Urbana Champaign에서 지리학 석사학위를 받았으며, 현재 Virginia Commonwealth University 의과대학 역학과에서 박사과정 중이다. 주요관심 분야는 의료 보건통계 분야이며, 현재 스트레스성 치사율과 Opioid Epidemic의 사회적 비용을 GIS와 공간 베이지안으로 추정하는 연구를 하고 있다.

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이준배는 미국 Texas Tech University에서 경제학 박사학위를 받았으며, 충북대학교 농업경제학 교수로서 재직 중에는 계량경제, 다변량 통계, 시계열분석에 관한 연구와 강의를 했고, 현재 퇴임해서 명예교수로 보건복지 분야에 관심을 가지고 청소년 비행과 노인 정신건강에 미치는 동태 영향분석과 예방대책을 제시하는 연구를 하고 있다.

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한국 노인의 자살생각 위험요인 통계분석:
패널 로짓 GLMM의 적용

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본 연구는 한국복지패널 2012년도부터 2017년도까지 6개년 종단자료를 활용하여 노인의 자살생각에 미치는 관련 요인의 영향도 추이를 분석하였다. 이를 위해 노인자살의 관련 요인들은 지역, 성 및 동거형태, 경제활동, 가정빈곤도, 노인복지, 병원진료, 우울, 그리고 자아 존중감 등으로 하였다. 본 패널자료의 고유한 내재적 속성을 고려하기 위해서, 인구 사회적 요인들을 고정효과 변수로 하고 그 외의 요인들은 임의효과 변수로 하는 임의절편 고정효과 로짓 GLMM 모형으로 분석하였다. 본 연구결과를 바탕으로 노인자살문제를 완화하기 위한 사회복지적 개입방안에 대하여 지역과 성 및 동거유형 간 차별화된 접근의 중요성을 논의하였다. 특히 성 및 동거형태별 노인 자살위험률에 미치는 영향력은 남자동거에 대해서 남자독거가 2.3배가 유의적으로 높았고, 반면에 여자독거는 유의적인 차이가 인정되지 않았다. 또한 남자 독거노인 그룹은 높은 우울과 낮은 자존감, 그리고 열악한 경제적 요인도 함께 연관되어 있었다. 따라서 이들에 대한 가족 결속력과 사회 지지망을 확대해서 자아존중감을 높이고 동시에 우울을 해결할 수 있는 예방적 프로그램들이 제공되어야 할 것이다.

주요 용어: 노인자살위험, 독거노인, 경시적 자료, 패널로짓 선형혼합모형