Research Article

Understanding the contribution of suicide to life expectancy in South Korea

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Contents

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Abstract

BACKGROUND
South Korea has the highest rate and highest rate of increase in suicide among developed countries. The suicide epidemic in Korea is an anomaly, and suicide rates are high for both men and women, with no signs of decreasing. Yet we do not know the extent to which suicide has reduced life expectancy in Korea.

OBJECTIVE
We investigated whether and to what extent the rapid increase in suicide has contributed to changes in Korean life expectancy, a key indicator of population health.

METHODS
We used a recently developed decomposition method that separates the contribution of suicide's effect on change in life expectancy into two parts: that due to change in the overall suicide incidence rate and that due to change in the mean age of suicide victims.

RESULTS
From 1995 to 2010, life expectancy increased by 6.5 years in Korea, with change in most causes of death contributing to its growth. We nonetheless find, as expected, that the rise in suicides reduced the increase in life expectancy from 1995 to 2010, so life expectancy in Korea is about 0.21 years lower than it would have been without the increase in suicides. Moreover, had the age of suicide victims remained stable, we project that Korea's life expectancy would be fully 0.70 years lower than it is.

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CONCLUSION

Although the growth in suicide was the largest single factor slowing the rise in Korean life expectancy, the effect would have been even larger had the age of suicide victims not increased.

1. Introduction

Suicide − intentional death resulting from a victim's own action − is the product of a complex interplay between individuals and society (Durkheim 1952). Since the mid-1990s, South Korea (hereafter Korea) has experienced an unprecedented increase in suicide, and currently has the third highest suicide rate in the world, after Guyana (44.2 per 100,000) and North Korea (38.5 per 100,000) (World Health Organization 2014). In 2010, Korea had both the highest suicide rate and the highest rate of increase in suicide among the Organization for Economic Co-operation and Development (OECD) countries (Figure 1). At 33.5 per 100,000, Korea's suicide rate was nearly 2.5 times higher than the average rate for OECD countries (13.3 per 100,000) (World Health Organization Statistical Information System 2014). For Korea, this rate translates into about 40 suicides every day, or about one suicide every 37 minutes. Indeed, the suicide epidemic has become one of the most important and urgent public health concerns in Korea (Kim and Yoon 2013).

The alarming rise in Korea's suicide rate has occurred alongside a rapid increase in life expectancy. In 1960, life expectancy in Korea was only 53.0 years, which was well below the OECD average; by 2012 it had risen to 81.4 years, surpassing the OECD average (World Bank Group 2013; Yang et al. 2010) (see Figure 2). This equates to an increase of nearly 28.4 years over the last five decades, or more than one-half year each year, a remarkable gain. With the rapid rise in the suicide rate that began in the mid-1990s, understanding the contribution of suicide to life expectancy has become more critical because it is important for designing effective public policies to promote better population health.

Figure 1: **Suicide trends in Korea, 1960−2012**
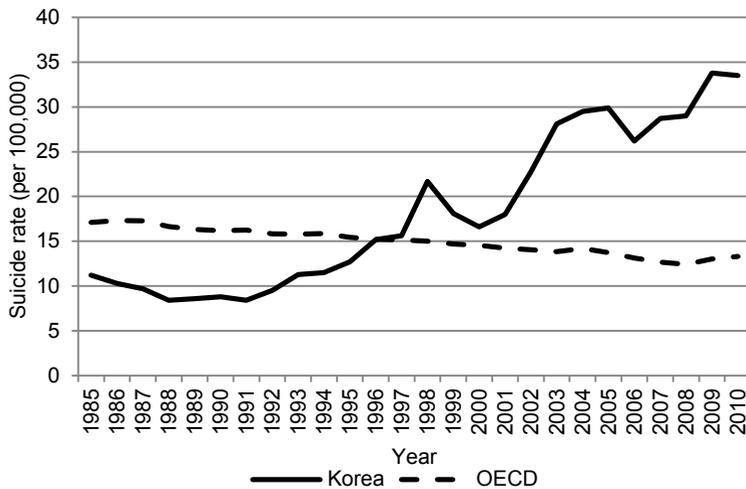
Figure 2: **Trends in life expectancy in Korea, 1960–2012**
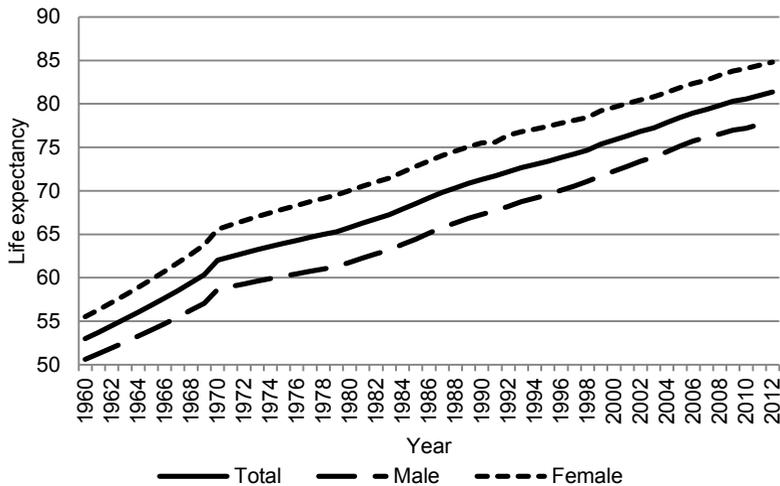
The effect of suicide on life expectancy depends on two factors, the proportion of people who commit suicide (that is, the lifetime risk of dying from suicide), and the average age of suicide victims. Hence the effect of change in suicide on change in life expectancy is a function of change in the proportion of people who commit suicide (the suicide rate) and change in the average age of suicide victims compared to their life expectancy. We subsequently describe a method for estimating the separate contributions of change in the suicide rate (the 'incidence component') from change in the average age of suicide victims (the 'age component'). The important point to note here is that change in the suicide rate is not the entire story. Because suicide victims tend to be disproportionately young or middle-aged, the effect of rising suicide rates on life expectancy can be substantially diminished if the age of the suicide victims also rises. Likewise, the effect of falling suicide rates can be diminished if the age of suicide victims declines.

To understand the contributions of suicide to life expectancy in Korea, this study examines how much the rise in suicide rate has reduced life expectancy in Korea and why, using the age-incidence decomposition method to separate the age component from the incidence component (Firebaugh et al. 2014). Specifically, this study addresses the following questions. Has the reduction been a) entirely a function of the change in suicide rate (i.e., no age component), or b) a function of change in suicide rates and an age component? If the reduction has been a function of change in suicide rates and an age component, is the age component positive (indicating that the adverse effect of the rising suicide rate has been attenuated), or negative (indicating that the adverse effect of the rising suicide rate has been amplified)?

2. Suicide in the Korean context

Given the unprecedented increase in suicide rates in Korea in the past two decades, its contribution to total mortality is worthy of study. The importance of considering the role of suicide in life expectancy is apparent: Suicide is the leading cause of death for all individuals in their teens, twenties, and thirties. In addition, it remains the second leading cause of death for all individuals in their forties and fifties, just behind cancer (Ha 2011). The impact of suicide on the total mortality rate was even more pronounced during the 1997–1998 economic crisis, when suicide deaths showed the most salient increase while all-cause mortality decreased for both sexes and all age groups (Khang, Lynch, and Kaplan 2005). In a recent study investigating the rapid increase in life expectancy in Korea, Yang and colleagues (2010) found that mortality from suicide actually decreased life expectancy among men by 0.2 years between 1983 and 2005 − a finding that illustrates the importance of suicide in decreasing life expectancy.

However, the age- and incidence-specific contributions of suicide to life expectancy in Korea remain unknown.

Korea provides a unique setting to enhance our understanding of suicide and its implications for population health, for two reasons. First, Korea has a unique history of rapid economic development along with significant sociodemographic changes in a short time span; these changes may have contributed to the rapid increase in suicide by weakening social cohesion. Following colonial exploitation (1910–1945) and the Korean War (1950–1953), Korea was a very poor country. However, through state-driven industrialization and foreign aid, Korea achieved extraordinary economic development. Gross national income per capita increased from less than $1,537 in 1960 to almost $30,254 in 2011 (both in 2011 US dollars) – more than a 20-fold increase (Kim et al. 2011; US Bureau of Labor Statistics 2015). This rapid economic growth was accompanied by rapid urbanization and demographic change, which in turn brought about changes in social values and traditions (Kim et al. 2011; Kwon, Chun, and Cho 2009). Although these changes are not unique to Korea, the time span in which they occurred was much shorter in Korea than in other countries. With these expeditious socioeconomic, political, demographic, and normative changes in Korea, some modern social forces may have weakened social cohesion and, as a result, individuals may have experienced anomie − that is, weakened ties to society (Durkheim 1952).

Second, Korea's suicide patterns and trends contrast significantly with those of other countries (see Figure 1). With a thriving economy in the late 1980s and early 1990s, suicide mortality in Korea decreased, but it started to increase significantly from the mid-1990s. For example, the suicide rate was 12.8 per 100,000 in 1990 and increased to 20.3 per 100,000 in 2000 and then to 33.5 per 100,000 in 2010 (OECD 2013). Korea's suicide epidemic was triggered by the economic crisis of 1997–1998[4], which led to broad structural readjustments and a skyrocketing unemployment rate. The rapid increase in suicide rates during this time (from 19.5 per 100,000 in 1997 to 28.8 per 100,000 in 1998) has been attributed to a rise in unemployment (Chang et al. 2009). Consistent with suicide patterns in other countries that have experienced similar economic crises, Korea's suicide rate appeared to drop afterward, until 2000. However, it then started to increase again and has continued to increase ever since (Hong, Bae, and Suh 2006). This pattern of rapid increase after economic stabilization is an anomaly. In addition, while other countries with high suicide rates (e.g., Hungary, Finland, Denmark, and Switzerland) have experienced decreasing or steady rates over the last two decades, Korea has experienced an annual increase of 16.8% during the same period (Hong, Bae, and Suh 2006). This extraordinary increase in Korea's suicide rate over the last two decades is also unique in that potential individual causes (e.g.,

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[4] In order to recover from this severe economic crisis the Korean government received an emergency rescue loan from the International Monetary Fund (IMF) (Khang, Lynch, and Kaplan 2005).

depression) as well as contextual causes (e.g., changes in family structure) of suicide are not unique to Korea (Ha 2011).

Despite these alarming suicide patterns and trends, scholarly and policy efforts to systematically investigate the causes and consequences of suicide in Korea have only recently emerged (Ha 2011), resulting in an "underemphasis on related research and fragmented prevention approaches" (Chen et al. 2011: 129). Thus a more systematic and comprehensive investigation of suicide is critical in order to resolve the current suicide epidemic by both reducing the current suicide rate and promoting future suicide prevention efforts. Because most previous studies on suicide have been conducted in Western countries, the findings of these Western-centric studies may not be applicable to Korea, whose suicide patterns, risk, and protective factors differ substantially (Chen et al. 2011; Hendin et al. 2008). For example, recent studies have found that socioeconomic situations (e.g., unemployment, financial problems) have greater impacts on suicidality and suicide in Asia than in the West (Chen et al. 2011; Liu et al. 2009; Rehkopf and Buka 2006). Furthermore, higher stigmatization of mental health problems and the Korean family-oriented culture may hinder those at risk from obtaining preventive resources, because of the preconception that the stigma of mental health problems may negatively affect the entire family (Chen et al. 2011).

To fashion more effective public policy for suicide prevention/intervention it is important to determine which groups are most at risk of suicide. By focusing on the age component of suicide, this study reveals that the rising overall suicide rate in Korea has been driven in large part by notably higher rates of suicide among the elderly. Therefore, by examining precisely how the rise in suicides has affected life expectancy in Korea, we identify the age groups that should be targeted to halt the growth in suicides among Koreans.

3. What contributes to change in life expectancy over time?

Life expectancy at birth is a tempo measure of mortality, as it measures the timing at which the event of interest (here, death) occurs (Bongaarts and Feeney 2006). However, in a multiple cause of death framework, the level of life expectancy depends on both the tempo (cause-specific mean age at death) and the quantum (probability of dying of cause *c*) of the event. In the multiple cause of death framework, then, part of the observed change in life expectancy can be due to change in cause-specific probabilities, or lifetime risks of dying of a given cause. We refer to this part as the 'incidence component'. To illustrate, consider Table 1, which reports the number of suicides per 1,000 Koreans by age group, based on life table deaths in 1995 and in 2010. From these results it is clear that, on the one hand, suicide is becoming more common, as indicated

by the higher death rates in 2010 compared to 1995 for each age group after age 15, and on the other hand, suicide victims are getting older, as the increase in number of suicides per 1,000 Koreans is larger at older ages. How have these two shifts contributed to the change in life expectancy in Korea? That is the question we address through age-incidence decomposition.

Table 1: **Number of suicides per 1,000 Koreans by age group, based on life table deaths in 1995 and in 2010**

Age Group	Year	
	1995	2010
0	0.0	0.0
1−4	0.0	0.0
5−9	0.0	0.0
10−14	0.1	0.1
15−19	0.4	0.5
20−24	0.6	1.0
25−29	0.7	1.5
30−34	0.6	1.5
35−39	0.7	1.6
40−44	0.7	1.7
45−49	0.8	2.0
50−54	0.8	2.1
55−59	0.7	2.3
60−64	0.7	2.4
65−69	0.8	3.1
70−74	0.9	3.8
75−70	0.7	4.3
80−84	0.5	4.2
85+	0.4	6.9
	10.1	39.0

3.1 Incidence component

Life expectancy is increased by shifts in causes of death from younger-age to older-age causes of death, and decreased by the reverse shift. The term 'incidence component' refers to the change in life expectancy attributable to such shifts in the causes of death. For change in life expectancy from time 1 to time 2, the incidence component for a specific cause c is $w_c(p_{c2} - p_{c1})$, where $p_{c2} - p_{c1}$ is change in the lifetime risk of

dying of cause c (suicide), that is, change in the proportion of life table deaths due to cause c (Firebaugh et al. 2014). The weight w_c differs for two-factor versus three-factor decomposition (described later). The total or all-cause incidence component is the sum of the cause-specific incidence components.

3.2 Age component

The remainder of the change in life-table life expectancy is due to change in cause-specific mean age at death (age component). If individuals die of the same causes (no incidence component) but at a later age, life expectancy will increase. The overall change (Δ) in life expectancy is the sum of the incidence and age components. In short:

$$\Delta e = effect\ of\ \Delta\ proportion\ of\ deaths\ by\ cause$$
$$+\ effect\ of\ \Delta\ mean\ age\ at\ death\ by\ cause$$
$$=\ incidence\ component\ +\ age\ component$$

By separating the incidence and age components we determine whether change in life expectancy is occurring because people are dying of different causes, or because they are dying of the same causes but at different ages (Acciai, Noah, and Firebaugh 2015; Firebaugh et al. 2014). Change in life expectancy is due to change in death rates, and age-incidence decomposition reveals the locus of the death rate changes that are driving the change in life expectancy. The age component is a function of cause-specific change in mean age at death, which in turn is a function of change in age-specific death rates within causes of death. Thus a large age component indicates that life expectancy is changing because of upward or downward shifts in age-specific death rates within causes of death. A large incidence component, by contrast, indicates that the change in life expectancy is attributable to change in the overall cause-specific death rates, or the lifetime risk of dying of different causes.

3.3 Two-factor versus three-factor decomposition

We can decompose the change in life expectancy by cause into either two factors or three factors, depending on whether we separate out the joint effect of change in cause-specific death rates and change in cause-specific mean age at death. The original two-factor method (Firebaugh et al. 2014) implicitly assigns one-half of this joint effect to the incidence component and one-half to the age component.

Alternatively, we could isolate the age component by weighting change in x_c (the cause-specific mean age at death) by the initial (time 1) value of p_c and isolate the incidence component by weighting change in p_c by the initial value of x_c. This forward decomposition method produces three components instead of two, since there is an interaction term that captures the joint effect of change in mean age at death and change in probability of death for each cause. In other words, we can extract the joint effect from the age and incidence components. This gives us the pure age and the pure incidence components, which represent the change in life expectancy between time 1 and time 2, due to change in cause-specific mean age at death and cause-specific probability of dying, net of their interaction—the joint component:

$$\Delta e = pure\ incidence\ component + pure\ age\ component + joint\ component$$

4. Data and methods

4.1 Data

Our data analyses proceeded in several stages. First, we constructed period multidecrement life tables following the classical approach (Carey 1989; Preston, Heuveline, and Guillot 2001) to determine the lifetime risk of dying and average age at death across multiple causes of death after eliminating the differences in population size and age composition between 1995 and 2010. Multidecrement life tables are constructed by computing cause-specific death probabilities from age-cause-specific death ratios. For suicide, we included different modes of suicide to investigate whether they changed between 1995 and 2010; these results may be useful for informing prevention policies aimed at specific suicide modes. We then decomposed the factors contributing to life expectancy, separating the part due to cause-specific incidence from the part due to cause-specific average age at death. By so doing we assessed the impact of suicide on life expectancy and pinpointed the forces behind the impact of suicide on life expectancy. Finally, we used multidecrement life tables to determine the separate contributions of suicide to life expectancy for men and women. Similar to Firebaugh et al. (2014), we examine how men and women contribute to change in life expectancy of the overall population, that is, men and women are treated as two groups within the same population, and not as separate populations. The pattern of results is the same when we analyze men and women separately. For both men and women, a large incidence component is substantially offset by the rising age of suicide victims. The incidence component is larger for men, however, which explains why men have

contributed more than women to the effect of suicide on the change in life expectancy in Korea (complete results available upon request).

We extracted data for the study from the mortality database of the World Health Organization (WHO) for the period 1995–2010 (World Health Organization Statistical Information System 2014). The WHO mortality data contain information on the underlying cause of death and basic sociodemographic information. In Korea it is mandatory to report all deaths within one month, and Korean death registration reached 100% by the late 1980s (Khang, Lynch, and Kaplan 2005; Yang et al. 2010).[5] We stratified the mortality data by cause of death to create the cause- and age-specific multiple-decrement life table data. We used the 10th revision of the International Classification of Diseases (ICD-10) to code causes of death. To reduce the number of causes, we collapsed them into nine broad categories (plus a residual category) representing key causes of death: cardiovascular diseases, cancer, chronic diseases, communicable diseases, suicide, external causes (other than suicide), mental and behavioral disorders, infant conditions, ill-defined causes, and minor causes not elsewhere classified (NEC). We adapted this scheme based on prior analyses (Acciai, Noah, and Firebaugh 2015; Firebaugh et al. 2014; Nau and Firebaugh 2012), but we created separate categories for causes that are relevant to our investigation (i.e., suicide, and mental and behavioral disorders). Appendix Table A-1 describes our cause grouping in more detail.

Following previous research (Ahn et al. 2012), we divided suicide into five modes: hanging (category X70 in ICD10), poisoning from pesticides (X68), poisoning from non-pesticides (X69), jumping (X80), and unspecified means (remaining categories in X). Although previous research has grouped poisoning in one overarching category, we split poisoning into two categories because they have distinct patterns between 1995 and 2010. In 1995, pesticide poisoning accounted for 29.7% of all suicide mortality, while nonpesticide poisoning accounted for about 13.0%. Pesticide poisoning declined faster than nonpesticide poisoning, accounting for 17.5% of all suicide mortality by 2010, compared with 8.3% for nonpesticide poisoning. Furthermore, consistent with previous research (Chang et al. 2009), we included deaths of undetermined intent (Y10-Y34 in ICD-10) to avoid the possible underestimation of suicide. We included suicide deaths of undetermined intent as a separate mode of suicide because classifying them in other suicide subcategories could distort the patterns by different suicide methods.

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[5] Infant deaths (neonatal death) may be underreported (Khang et al. 2005).

4.2 The age-incidence decomposition method

Period life expectancy is a summary measure of the mortality pattern in a given population at a certain point in time; it represents the average length of life of newborns, under the hypothesis that they will experience the current age-specific mortality rates throughout their lives. As noted earlier, causes of death can contribute to changes in life expectancy through two underlying processes: change in cause-specific average age at death (or change in the tempo of the event), and change in the probability of dying of each cause (or change in the quantum of the event). Although previous decomposition methods jointly partition by age and cause, they do not determine how much of the change is attributable to change in age with cause-specific lifetime risk fixed (age component), or to change in cause-specific lifetime risk with age at death fixed (incidence component).

To separate the age and incidence components, note that life expectancy, e_0, equals the sum of the cause-specific mean age at death, x_c, weighted by the cause-specific probability of death, p_c:

$$e_0 = \sum_c p_c \, x_c \qquad (1)$$

where the subscript c indicates the cause of death. Thus the change in life expectancy between time 1 and time 2 (or the difference in life expectancy between populations 1 and 2) is:

$$e_{02} - e_{01} \ = \ \sum_c p_{c2} x_{c2} - \sum_c p_{c1} x_{c1} \qquad (2)$$

Firebaugh et al. (2014) show that the contribution of a single cause c to the change in life expectancy is:

$$contribution \ of \ cause \ c \ = \ p_{c2}(x_{c2} - \bar{e}) - p_{c1}(x_{c1} - \bar{e}), \qquad (3)$$

where $\bar{e}$ is the simple average life expectancy for the two time points. From equation (3) we see that the contribution to the overall change in life expectancy can derive from 1) change in the cause-specific mean age at death ($x_{c1} \neq x_{c2}$) and 2) change in the allocation of the causes of death ($p_{c1} \neq p_{c2}$).

The age-incidence decomposition isolates these two sources of change. In the two-factor approach, used in Acciai, Noah, and Firebaugh (2015) and in Firebaugh et al. (2014), the age component for cause c is as follows:

$$age \ component \ for \ cause \ c \ = \ \bar{p}_c(x_{c2} - x_{c1}), \qquad (4)$$

where $\bar{p}_c$ is the simple average proportion for cause c at the two points in time. Change in age at death has greater impact on life expectancy when the cause of death is common (large $\bar{p}_c$), just as one would expect. The two-factor method separates out the incidence component by weighting change in the probability of dying of cause c, $(p_{c2} - p_{c1})$, by $(\bar{x}_c - \bar{e})$:

$$incidence\ component\ for\ cause\ c = (\bar{x}_c - \bar{e})(p_{c2} - p_{c1}), \qquad (5)$$

where $\bar{x}_c$ is the simple average $(x_{c1} + x_{c2})/2$. Change in lifetime risk has greater impact on life expectancy for causes (such as homicide and Alzheimer's) where mean age at death is further from $\bar{e}$, the average of the life expectancies for both years. Under the assumption that causes of death are exhaustive and mutually exclusive, the sum of the age and incidence components over causes of death is equal to the change in life expectancy between time 1 and time 2:

$$e_{02} - e_{01} = \sum_c \bar{p}_c(x_{c2} - x_{c1}) + \sum_c (\bar{x}_c - \bar{e})(p_{c2} - p_{c1})$$
$$= \text{Age Component} + \text{Incidence Component for two-factor method} \qquad (6).$$

Three-factor decomposition weights the differences in equation (6) by initial values rather than by average values. For example, to determine how much of the change in life expectancy is uniquely attributable to change in the mean age at death for a specific cause, we weigh the observed change, $x_{c2} - x_{c1}$, by p_{c1} rather than by $\bar{p}_c$. In effect, we suppose that the proportion of people dying of each cause had remained fixed at time 1, while the cause-specific mean age at death changed in the manner observed, and ask: How much would life expectancy have increased or decreased? Likewise, to generate the incidence component, we suppose that cause-specific mean age at death remained fixed at its initial values, and use observed change in the p_cs to estimate the unique contribution of change in the allocation of causes of death.

Because the age and incidence components just described are based on initial values as weights, they do not capture the joint effect of change in cause-specific mean age at death and change in the allocation of causes of death. Three-factor age-incidence decomposition, then, consists of these three elements:

$$e_{02} - e_{01} = \sum_c p_{c1}(x_{c2} - x_{c1})$$
$$+ \sum_c (x_{c1} - \bar{e})(p_{c2} - p_{c1}) + \sum_c (p_{c2} - p_{c1})(x_{c2} - x_{c1})$$
$$= \text{Pure Age Component} + \text{Pure Incidence Component} + \text{Joint Effect} \quad (7).$$

Finally, the age-incidence method can be extended to derive the contribution of changes in the mortality regime to the change in life expectancy for specific subpopulations. For instance, if heart disease is found to account for one year of the increase in life expectancy between time 1 and time 2, one might ask whether this increase is shared equally between two groups (say, blacks and whites, or men and women). In this paper we first determine the extent to which the life expectancy trend in Korea from 1995 to 2010 derives from changes in the mortality regime of men and women combined and then assess whether the contribution of suicide to the total change in life expectancy is mainly due to changes in the pattern of suicide among women or among men.
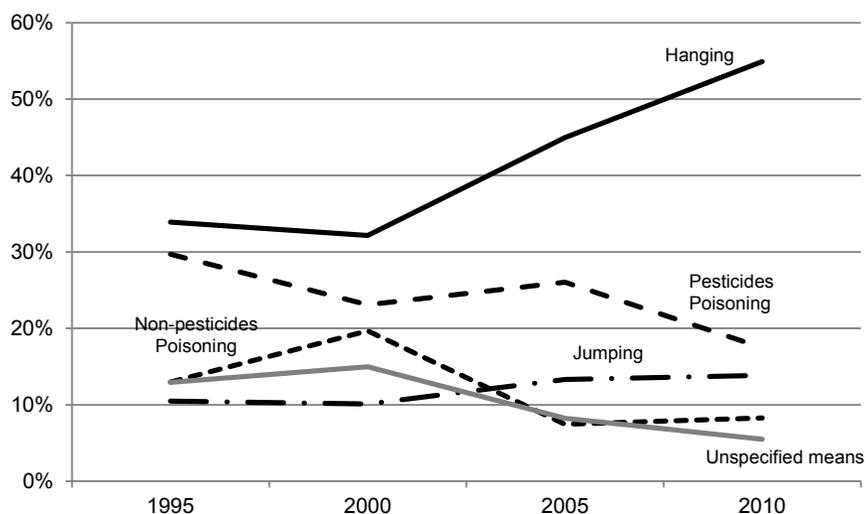
5. Results

5.1 Descriptive patterns

Table 2 provides the cause-specific probability of death and mean age at death in Korea based on multidecrement life tables in 1995 and 2010. The number of suicide deaths increased considerably over this 15-year period, from 1.0% of all life table deaths in 1995 to 3.9% of all life table deaths in 2010.. This exceptional increase in suicide occurred for both males and females. Suicide deaths accounted for 1.5% of all deaths for males in 1995 (from .007/.469 in Table 2), but this figure rose to 5.1% (.023/.454 in Table 2) in 2010. Similarly, for females, suicide deaths accounted for 0.6% of all deaths in 1995 but 2.7% in 2010. Moreover, the method of suicide changed between 1995 and 2010, with hanging and jumping increasing significantly and pesticide poisoning becoming less common (Figure 3). Except for jumping, males and females died using similar modes of suicide (jumping accounted for 14.5% of female suicides in 2010 versus 9.6% of male suicides). Appendix Table A-2 reports the observed number of deaths, both in absolute and relative terms, for each cause.

Table 2: Probability of death and mean age at death in Korea, by cause and sex: 1995 and 2010

Cause of death	Probability in 1995			Mean age in 1995			Probability in 2010			Mean age in 2010		
	Total	Male	Female	Total	Male	Female	Total	Male	Female	Total	Male	Female
Cardiovascular disease	0.292	0.123	0.169	73.6	69.9	76.2	0.252	0.097	0.155	81.7	77.3	84.4
Cancer	0.173	0.106	0.066	66.0	64.9	67.8	0.227	0.132	0.094	73.6	71.9	76.0
Chronic diseases	0.099	0.056	0.042	70.8	66.3	76.7	0.107	0.046	0.061	82.1	77.0	85.9
Communicable diseases	0.075	0.040	0.034	77.4	73.7	81.7	0.123	0.061	0.062	86.4	83.8	88.9
Other external causes	0.059	0.040	0.020	53.6	49.9	60.9	0.037	0.021	0.016	72.0	65.3	81.0
Mental and behavioral	0.027	0.009	0.018	81.6	73.1	85.6	0.028	0.008	0.019	89.0	83.8	91.3
Infant conditions	0.002	0.001	0.001	9.4	7.2	12.0	0.003	0.002	0.001	5.5	4.7	6.4
Suicide	**0.010**	**0.007**	**0.003**				**0.039**	**0.023**	**0.015**			
Hanging	0.003	0.002	0.001	53.8	51.9	58.7	0.016	0.010	0.005	60.3	60.3	60.3
Poisoning (pesticides)	0.003	0.002	0.001	54.3	54.0	55.0	0.007	0.005	0.003	74.0	72.2	77.3
Poisoning (non-pesticides)	0.001	0.001	0.000	51.8	50.6	53.5	0.002	0.001	0.001	55.1	52.2	61.5
Jumping	0.001	0.001	0.001	53.6	52.4	54.8	0.004	0.002	0.002	61.9	60.2	63.8
Unspecified means	0.001	0.001	0.000	48.5	47.2	51.3	0.002	0.001	0.001	58.1	54.5	65.0
Undetermined deaths	0.001	0.000	0.000	51.8	49.5	55.7	0.008	0.004	0.003	75.8	72.0	81.1
Ill-defined causes (NEC)	0.239	0.078	0.161	86.8	83.4	88.5	0.152	0.050	0.102	89.6	84.9	92.0
NEC - Not elsewhere classified	0.025	0.009	0.015	73.8	67.1	78.0	0.033	0.013	0.020	81.6	76.6	84.7
Total	1.000	0.469	0.531	74.2			1.000	0.454	0.546	80.7		

Figure 3: Trends in suicide methods, 1995–2010

Source: Table 2.

5.2 Decomposition results

Life expectancy in Korea increased from 74.2 in 1995 to 80.7 in 2010 (see Table 2). The 6.5-year increase in life expectancy is entirely attributable to changes in cause-specific age at death, since the all-cause age component was 7.9 years (Table 3). In fact, the average age at death increased over this period for all causes of death except infant mortality, which declined by 3.9 years (Table 3). The all-cause incidence component, by contrast, is negative (−1.4 years), indicating that if the cause-specific average age at death had remained the same, life expectancy in 2010 would have been 1.4 years lower than it was in 1995 because of a higher probability in 2010 of dying from causes that strike at younger ages (such as suicide) and a lower probability of dying from causes that strike at older ages.

While the change in suicides reduced life expectancy in Korea between 1995 and 2010, the change in most other causes of death increased life expectancy. The major contributor to this increase was change in cardiovascular disease, which alone accounted for 2.2 years (or over one-third) of the total change in life expectancy. The cardiovascular effect was due entirely to the rising age of cardiovascular victims (Table 3). Changes in cancer, chronic diseases, communicable diseases, and other external causes contributed similarly to the increase in life expectancy − just over one year in each case. A smaller, but still positive, contribution came from mental and behavioral disorders and from minor causes not elsewhere classified. On the other hand, similar to change in suicide, change in ill-defined causes and (to a much lower extent) infant conditions reduced life expectancy. These three causes served to depress the increase in life expectancy. In particular, life expectancy would have increased an additional 0.7 years if the mortality patterns associated with these three causes of death had not changed over time. In 2010, fewer deaths were assigned to the category of ill-defined causes, probably because of improved medical diagnostic instruments and practices. The lower probability of dying of this cause, which has the highest cause-specific average age at death, contributes to a lower life expectancy. In short, results show that the age component is preponderant for all the causes that contribute positively to the change in life expectancy, while the incidence component is preponderant for the three causes with an overall negative contribution (infant conditions, suicide, and ill-defined causes).

Table 3: **Cause-specific age and incidence components of the change in life expectancy in Korea, 1995–2010: Two-factor decomposition**

Cause of death	Changes in life expectancy, 1995–2010		
	Proportion	Age at death	Total
Cardiovascular disease	0.00	2.20	2.20
Cancer	−0.41	1.51	1.10
Chronic diseases	−0.01	1.16	1.15
Communicable diseases	0.21	0.89	1.10
Other external causes	0.33	0.89	1.22
Mental and behavioral disorders	0.01	0.20	0.21
Infant conditions	−0.08	−0.01	−0.09
Suicide (total)	**−0.51**	**0.30**	**−0.21**
Hanging	−0.26	0.06	−0.19
Poisoning (pesticides)	−0.06	0.10	0.04
Poisoning (nonpesticides)	−0.02	0.01	−0.02
Jumping	−0.07	0.02	−0.05
Unspecified means	−0.01	0.01	0.00
Undetermined deaths	−0.10	0.10	0.00
Ill-defined causes	−0.95	0.55	−0.40
NEC - Not elsewhere classified	0.00	0.23	0.23
	−1.41	**7.93**	**6.52**

Note: Components calculated from probabilities and ages in Table 2.

For other causes of death the increase in the average age at death outweighed any negative incidence effect. In the case of cancer, for example, the incidence effect of −0.41 years was more than offset by the positive age effect of 1.51 years, so cancer's net contribution to change in life expectancy was positive (+1.1 years). In the case of suicide, the positive age effect was not large enough to offset the negative incidence effect of –0.51 in the two-factor decomposition. This negative contribution of suicide to life expectancy was greatly offset by a positive age effect (0.30) due to the rising average age of suicide victims. The net result, then, was only a 0.21-year reduction in life expectancy (Figure 4). With a classic decomposition-by-cause approach, we would have concluded that change in suicide reduced life expectancy by 0.21 years between 1995 and 2010. Using the age-incidence decomposition, however, yields further

insights, revealing that the adverse effect on life expectancy due to the rising proportion of suicide deaths would have been even greater if the age at death of suicide victims had not increased as well. We find a similar pattern for ill-defined causes of death, where a large negative incidence effect is partially offset by a positive age effect (see Figure 4).

Figure 4: **Key cause-specific components of the changes in life expectancy in Korea, 1995–2010, based on two-factor age-incidence decomposition**
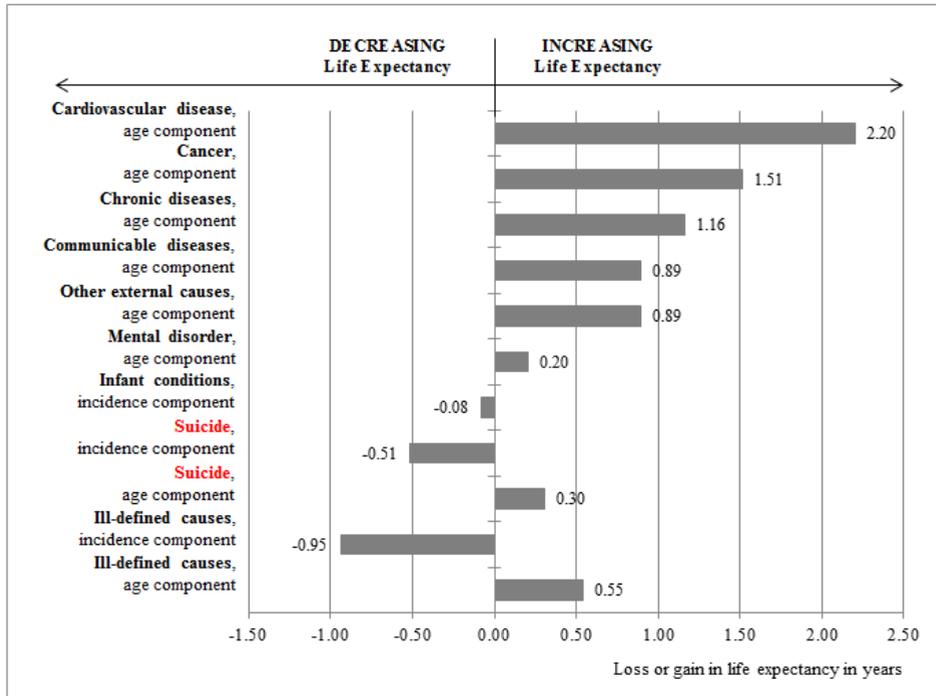
Different modes of suicide contributed differently to the reduction in life expectancy. The mode that accounts for the largest reduction in life expectancy is hanging. The incidence effect of hanging suicide alone accounted for –0.26 of a year, and its age effect accounted for 0.06 of a year. Overall, hanging suicide accounted for a 0.19 of a year reduction in life expectancy, or about 90% of the total suicide effect on life expectancy. The mode that accounts for the second largest reduction in life expectancy is jumping, with an incidence effect of –0.07 of a year and an age effect of 0.02 of a year. The large incidence effects of hanging and jumping mirror the

descriptive patterns, as both modes of suicide increased significantly from 1995 to 2010. Pesticide poisoning had a large positive age effect, indicating that among suicide victims in Korea the elderly are increasingly likely (relative to the young) to commit suicide by using pesticides.

For all causes of death combined, the mortality pattern for men and women contributed similarly (52.1% and 47.9% respectively) to the increase in life expectancy between 1995 and 2010 (Appendix Table A-3). However, the contribution of suicide death is quite unbalanced across gender. The decrease in life expectancy due to suicide derives mostly from changes in the mortality pattern of men (76%). In fact, compared with women, men's suicide rate increased more, and their mean age at death increased less. Therefore, although the suicide rate increased for both men and women, men's suicide mortality pattern had a larger negative effect on the overall life expectancy (–0.15 year versus –0.05 year).

Finally, Table 4 reports the three-factor decomposition results for suicide. The results reveal that if the average age of suicide victims had remained stable, the rising suicide rate in Korea would have reduced life expectancy by 0.7 years rather than by the actual reduction of 0.2 years. On the other hand, had the suicide rate not changed, the rising age of suicide victims would have added 0.12 years to the life expectancy of Koreans. The interaction effect is also positive in the three-factor decomposition: The rise in the average age for suicide victims 'increased' life expectancy in the sense that it muted the effect of the rise in the suicide rate. Had the average age not risen, the rising suicide rate would have depressed life expectancy more than it did.

Table 4: **Suicide's contribution to change in life expectancy in Korea, 1995-2010: Two-factor and three-factor age-incidence decomposition, by suicide method**

	Two-factor decomposition		Three-factor decomposition		
Cause of death	**Incidence**	**Age**	**Incidence**	**Age**	**Interaction**
Suicide	**–0.51**	**0.30**	**–0.70**	**0.12**	**0.38**
Hanging	–0.26	0.06	–0.30	0.02	0.08
Poisoning (pesticides)	–0.06	0.10	–0.10	0.06	0.09
Poisoning (non-pesticides)	–0.02	0.01	–0.02	0.00	0.00
Jumping	–0.07	0.02	–0.08	0.01	0.03
Unspecified means	–0.01	0.01	–0.01	0.01	0.00
Undetermined deaths	–0.10	0.10	–0.18	0.01	0.17

6. Discussion and conclusion

With the unprecedented rise in suicide rates in Korea in the past two decades, we set out to investigate the contribution of suicide to change in life expectancy in Korea from 1995 to 2010. Given the rapid increase in suicide, it puzzled us that the change in suicide had reduced life expectancy by only 0.2 years among men in Korea between 1983 and 2005 (Yang et al. 2010). Perhaps the impact of rising suicide rates on life expectancy had been muted by the rising age of suicide victims. To address this issue, we examined whether and to what extent suicide reduced life expectancy for both women and men between 1995 and 2010 using the new age-incidence decomposition method. Moving beyond standard decomposition approaches, this new method allowed us to separate the contribution of suicide's age and incidence components to change in life expectancy.

Our study produced three key findings. First, the increasing incidence of suicides was the single largest factor in dampening the rise in life expectancy in Korea.[6] Consistent with the finding of Yang et al. (2010) that suicide decreased life expectancy by 0.2 years among men between 1983 and 2005, we found that suicide reduced the life expectancy by 0.2 years between 1995 and 2010. Unlike that study, however, we decomposed this contribution of suicide to life expectancy into an age component and an incidence component, because the reduction in life expectancy due to suicide is a function of a change in overall suicide rates (incidence component) plus an increasing average age of suicide deaths. In fact, the adverse effect of rising suicide rates on life expectancy would have more than tripled (from 0.2 years to 0.7 years) if the age at death of suicide victims had not increased as well. These findings add to our understanding of how the rise of suicide affects life expectancy in Korea. Our findings about the age component also suggest that policymakers should keep in mind that rising suicide in Korea is being driven disproportionately by rising rates among the elderly.

Second, suicide methods changed between 1995 and 2010, and they contributed to the reduction in life expectancy differently. While hanging and jumping accounted for one-third of all suicide deaths in 1995, they accounted for 55% of suicides in 2010. As a result, hanging and jumping contributed to the reduction in life expectancy through their increased popularity (and thus large negative incidence components). Pesticide poisoning, on the other hand, became relatively less common, and apparently more favored among the elderly, as reflected in a positive age component. The increasing average age at death for pesticide poisoning suicide is consistent with previous research findings that pesticide poisoning has become more prevalent among the elderly (Cha, Khang, and Lee 2014). Despite public policy discourse emphasizing the increased suicide by pesticide poisoning in the last decades (Kim et al. 2011; Yip 2008), then, our

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[6] Only 'ill-defined causes' (an aggregate of many factors) had a larger dampening effect.

results indicate that the rise of suicide by pesticide poisoning actually had much less effect on life expectancy than other modes of suicide such as hanging and jumping.

These findings suggest that suicide prevention will require efforts that are specific to particular suicide methods in order to reduce suicide among specific subpopulations. For example, for the at-risk older population, policies should try to reduce access to lethal pesticides by a strict pesticide control system. Designing prevention policies for hanging is not as straightforward because most hangings occur at home (Chen et al. 2011). However, given that hanging is the most frequently used method for suicide and is increasing rapidly, the need for policies to systematically monitor those at-risk is imperative. Community organizations and government agencies should consider developing and implementing more systematic monitoring, such as routine home visits for disadvantaged elderly individuals living alone.

Third, the contribution of suicide deaths to life expectancy is unbalanced across gender, with men contributing more to the reduction in life expectancy (Appendix Table A-3). Men's suicide rate increased more than women's, and their mean age at death increased less. This is not surprising because the suicide rate is significantly higher for men than for women (Cheong et al. 2012), and suicide has been identified as the second most important cause of death responsible for widening the gender gap in life expectancy, after only lung cancer (Yang et al. 2012). To explain this gender difference in suicide rates in Korea, previous studies have argued that men choose more effective suicide methods (Ahn et al. 2012; Cheong et al. 2012). However, our results show that men and women generally chose similar suicide methods, with the exception of jumping, which is chosen by more women than men. The increasing gender gap in suicide apparently is not attributable to different suicide methods, so future research should look elsewhere for the specific mechanisms creating the higher suicide rates among men than among women.

In investigations of the effect of suicide on life expectancy, the biggest concern centers on the accuracy of cause-of-death coding practices, particularly for suicide deaths (Khang et al. 2005), where underreporting and misclassification might occur. Although Korea's death registration reached 100% by the 1980s with mandatory reporting requirements (Khang et al. 2005; Yang et al. 2010), suicide deaths might still be underreported. Suicide deaths are also available from the Korean National Policy Agency. These estimates are based on crime investigation reports rather than death certificates, and the number of suicide deaths derived from crime investigation reports is significantly higher than that from death certificates (e.g., 7,709 versus 4,840 deaths in 1995) (Bark 2007; Kim et al. 2010). However, scholars have argued that the number of suicide deaths derived from crime investigation reports may be overestimated because police often attribute non-homicide deaths to suicide in the absence of an autopsy. Furthermore, the discrepancy in suicide death numbers between these data

sources has been narrowing over the years (Kim et al. 2010). On the other hand, the number of suicide deaths obtained from death certificates may be underestimated because families of the deceased may be reluctant to report suicide as the cause of death because of the stigma of suicide (Chan et al. 2014). For instance, when faced with competing causes of death because of unclear intentions (e.g., car accidents versus suicide), families or doctors may prefer to classify deaths as being from nonsuicidal causes (Chan et al. 2014). However, these concerns are not unique to our study, and we included a separate category for deaths of undetermined intent in order to examine how they changed from 1995 to 2010 and to account for the potential underestimation of suicide resulting from misclassification.

In summary, we found that suicide was the largest single factor retarding the rise in life expectancy between 1995 and 2010 in Korea. Moreover, as we show, the size of its contribution was determined by both an incidence component (based on a rise in the overall suicide rate) and an age component (based on the increasing average age at death of suicide victims). Significantly, the adverse effect of rising suicide on life expectancy was greatly diminished by the increasing average age of suicide victims: Without this modifying effect, suicides would have reduced the rise in life expectancy over this period by an estimated seven-tenths of a year instead of two-tenths of a year.

The results of this study have important policy implications and suggestions to make for future research. The findings have identified suicide as the largest single factor reducing the rise in life expectancy in Korea, and revealed that the increasing average age of suicide victims somewhat masked the profound effect of suicide. As discussed earlier, one clear implication is that policymakers should explicitly consider the disproportionately rising suicide rates among the elderly when developing and implementing more systematic prevention and intervention efforts. One possible approach is to target specific geographic areas with a high proportion of elderly people (e.g., rural communities). Furthermore, it may be useful to target the elderly who have been exposed to suicide – as measured by having someone close who either attempted or committed suicide – as individual-level exposure to suicide is a key risk factor for individuals' suicidality (Lee, Kim, and Shim 2013). Another clear implication is the need for the Korean government to increase resources allocated for suicide prevention effort at the national level, given the serious consequence of suicide on population health. Although in 2012 the Korean government enacted the Suicide Prevention Law to reduce suicide, only about seven million dollars were allocated for suicide prevention efforts in 2013, compared to 130 million dollars in Japan (World Health Organization 2014). Future reasearch should examine the effectivness of this measure. Future research should also investigate the specific reasons for the increase in suicide among the elderly. For example, it may be associated with high relative poverty status (Khang et al. 2005), as nearly half (48.6%) of the elderly lived in poverty in 2011, which is four

times higher than the OECD average (12.8%) (OECD 2014). In addition, the discrepancy in timing between rapid population aging and the social welfare system may exacerbate the negative consequences of poverty among the elderly. Understanding such specific mechanisms will provide critical insights for developing and implementing more systematic prevention and intervention efforts. These findings suggest that suicide is a critical factor in understanding population health in Korea, and there is a need for further nuanced and systematic research. Our work shows the impact that suicide has on population health and, in particular, the mechanisms through which it affects (i.e., decreases) life expectancy. While we have pinpointed the aggregate patterns, more research is needed to understand the individual- and contextual-level factors that are associated with suicide in Korea.

7. Acknowledgements

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Appendix

Table A-1:   Cause grouping and corresponding ICD-10 codes

Cause of death	Subcategory	Code
Cardiovascular disease		I00-I99
Cancers		C00-D48.9
Chronic diseases	Chronic lower respiratory diseases	J40-J47
	Alzheimer's	G30-G30.9
	Diabetes	E10-E14.9
	Nephritis, nephrosis, nephrotic symptoms	N00-N07.9; N17-N19; N25-N27.9
Communicable diseases	Influenza and pneumonia	J10-J18.9
	Septicemia	A40-A41.9
	HIV/AIDS	B20-B24.9
	Other infectious diseases	A00-B99
Other external causes	Homicide	X85-Y09.9
	Traffic accidents	V02-V04.9; V09-V09.9; V23-V14.9; V19-89.9
	Other external causes	Remaining codes V01-V1.9, V90-Y89.9
Mental and behavioral disorders	Mental disorders	F1-F48
Infant conditions	Perinatal deaths	P00-P96
	Congenital anomalies	Q00-Q99
Suicide		X60-X84.9
Hanging		X70
Poisoning (pesticides)		X68
Poisoning (nonpesticides)		X69
Jumping		X80
Unspecified means		Remaining codes X60-X84.9
Undetermined intent		Y10-Y34
Ill-defined causes (NEC)	Not elsewhere classified	R00-R99
Minor causes (Residual)	All codes not listed above	

Table A-2: **Overall and gender-specific mortality trends, Korea 1995–2010**

	1995			2010		
Cause of death	Total	Male	Female	Total	Male	Female
Cardiovascular disease	62,718 (26.34%)	30,570 (22.71%)	32,148 (31.06%)	56,119 (21.97%)	26,740 (18.78%)	29,379 (25.99%)
Cancer	50,713 (21.30%)	32,421 (24.08%)	18,292 (17.67%)	73,147 (28.64%)	45,746 (32.13%)	27,401 (24.24%)
Chronic diseases	27,744 (11.65%)	18,392 (13.66%)	9,352 (9.04%)	28,302 (11.08%)	15,530 (10.91%)	12,772 (11.30%)
Communicable diseases	16,279 (6.84%)	9,981 (7.41%)	6,298 (6.08%)	25,213 (9.87%)	14,393 (10.11%)	10,820 (9.57%)
Other external causes	28,409 (11.93%)	20,815 (15.46%)	7,594 (7.34%)	13,894 (5.44%)	9,722 (6.83%)	4,172 (3.69%)
Mental and behavioral disorders	5,14 (2.16%)	2,360 (1.75%)	2,788 (2.69%)	4,947 (1.94%)	2,086 (1.47%)	2,861 (2.53%)
Infant conditions	1,240 (0.52%)	70 (0.52%)	539 (0.52%)	1,323 (0.52%)	762 (0.54%)	561 (0.50%)
Suicide	5,146 (2.16%)	3,519 (2.61%)	1,627 (1.57%)	18,193 (7.12%)	12,071 (8.48%)	6,122 (5.42%)
Hanging	1,641 (0.69%)	1,251 (0.93%)	390 (0.38%)	8,549 (3.35%)	5,720 (4.02%)	2,829 (2.50%)
Poisoning (pesticides)	1,437 (0.60%)	967 (0.72%)	470 (0.45%)	2,719 (1.06%)	1,875 (1.32%)	844 (0.75%)
Poisoning (nonpesticides)	628 (0.26%)	386 (0.29%)	242 (0.23%)	1,287 (0.50%)	945 (0.66%)	342 (0.30%)
Jumping	508 (0.21%)	269 (0.20%)	239 (0.23%)	2,159 (0.85%)	1,186 (0.83%)	973 (0.86%)
Unspecified means	626 (0.26%)	446 (0.33%)	180 (0.17%)	852 (0.33%)	603 (0.42%)	249 (0.22%)
Undetermined deaths	306 (0.13%)	200 (0.15%)	106 (0.10%)	2,627 (1.03%)	1,742 (1.22%)	885 (0.78%)
Ill-defined causes	34,482 (14.48%)	12,947 (9.62%)	21,535 (20.81%)	25,850 (10.12%)	11,346 (7.97%)	14,504 (12.83%)
NEC − Not elsewhere classified	6,253 (2.63%)	2,924 (2.17%)	3,329 (3.22%)	8,417 (3.30%)	3,962 (2.78%)	4,455 (3.94%)
	238,132 (100%)	134,630 (100%)	103,502 (100%)	255,405 (100%)	142,358 (100%)	113,047 (100%)

Table A-3: **Cause-specific male and female contributions to changes in life expectancy in Korea, 1995–2010**

Cause of death	Changes in life expectancy, 1995–2010		
	Male	**Female**	**Total**
Cardiovascular disease	0.92	1.28	2.20
Cancer	0.60	0.50	1.10
Chronic diseases	0.60	0.55	1.15
Communicable diseases	0.54	0.57	1.11
Other external causes	0.83	0.38	1.22
Mental and behavioral disorders	0.09	0.12	0.21
Infant conditions	−0.05	−0.04	−0.09
Suicide	−0.15	−0.05	−0.21
Hanging	−0.12	−0.08	−0.19
Poisoning (pesticides)	0.02	0.02	0.04
Poisoning (nonpesticides)	−0.02	0.00	−0.02
Jumping	−0.03	−0.02	−0.05
Unspecified means	0.00	0.00	0.00
Undetermined deaths	−0.01	0.02	0.00
Ill−defined causes	−0.09	−0.31	−0.40
NEC − Not elsewhere classified	0.09	0.14	0.23
	3.38	**3.14**	**6.52**