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Original article

Inequalities in External-Cause Mortality in 2018 across Industries in Republic of Korea



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ABSTRACT

Background: External-cause mortality is an important public health issue worldwide. Considering its significance to workers' health and inequalities across industries, we aimed to describe the state of external-cause mortality and investigate its difference by industry in Republic of Korea based on data for 2018.

Methods: Data obtained from the Statistics Korea and Korean Employment Information System were used. External causes of death were divided into three categories (suicide, transport accident, and others), and death occurred during employment period or within 90 days after unemployment was regarded as workers' death. We calculated age- and sex-standardized mortalities per 100,000, standardized mortality ratios (SMRs) compared to the general population and total workers, and mortality rate ratios (RRs) across industries using information and communication as a reference. Correlation analyses between income, education, and mortality were conducted.

Results: Age- and sex-standardized external-cause mortality per 100,000 in all workers was 29.4 (suicide: 16.2, transport accident: 6.6, others: 6.6). Compared to the general population, all external-cause and suicide SMRs were significantly lower; however, there was no significant difference in transport accidents. When compared to total workers, wholesale, transportation, and business facilities management showed higher SMR for suicide, and agriculture, forestry, and fishing, mining and quarrying, construction, transportation and storage, and public administration and defense showed higher SMR for transport accidents. A moderate to strong negative correlation was observed between education level and mortality (both age- and sex-standardized mortality rates and SMR compared to the general population).

Conclusion: Inequalities in external-cause mortalities from suicide, transport accidents, and other causes were found. For reducing the differences, improved policies are needed for industries with higher mortalities.

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1. Introduction

External-cause mortality is an important public health issue worldwide. While it was previously recognized as an inevitable and unpredictable accident, it is now regarded as a preventable problem like chronic diseases [1]. According to global health

estimates by the World Health Organization, death from injuries accounted for 8.0% of global death, and more than 4.4 million people died from both intentional and unintentional injuries in 2018 [2]. In Republic of Korea, death from external causes accounted for 9.4% of all deaths in 2018. This is higher than the global average, and the suicide rate in Republic of Korea is the

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highest among Organisation for Economic Co-operation and Development countries [3,4].

External-cause mortality has a more significant impact on workers' health than public health. In the fiscal year 2015 in Japan, accident and suicide together accounted for 4.7% of all deaths among the entire population, while the proportion was 11.0% for employed persons [5]. Additionally, there are differences in external-cause mortality according to industry and occupation. A study in Republic of Korea reported the highest external-cause mortality in agriculture, forestry, and fishing among all occupation categories [6], and a study on the injury epidemiology of Korean workers showed higher hospitalization risks in agriculture, hunting and forestry, and mining and quarrying [7]. Similarly, studies in Japan reported higher all-cause and external-cause mortality among workers engaged in the primary industry sector [8] and the highest risk of suicide among workers in mining, fisheries, and agriculture among all industries [9]. Additionally, differences in the risk of suicide among industries have increased in the last 30 years, while differences in the risk of cardiovascular diseases have decreased [10].

In 2018, total deaths by external causes recognized as industrial accidents in Republic of Korea were 971, and the mortality rate per 1,000 was 0.05. The number of deaths was the highest in the construction industry, with 485 cases. However, the mortality rate per 1,000 was the highest in the mining industry at 1.11, while the construction industry was at 0.16, and no other industry exceeded the rate of 0.3 [11]. In the United States, the fatal work-related injury rate per 100,000 was 0.7 in health care and social services, whereas it was 29.2 in agriculture, forestry, and fishing. Furthermore, male nonspecialized manual workers showed a significant hazards ratio compared to high-qualified nonmanual workers in a study in Italy [12,13]. Therefore, it can be assumed that inequality in external-cause mortality across occupations and industries is a global occupational health issue. Although a previous study reported external-cause mortality inequality across occupations, its difference by the industry remains unclear in Republic of Korea [6]. Furthermore, although there is an annual report of workers' compensation by the Ministry of Employment and Labor, these statistics have limitations, as they are based only on compensated cases and on the year of compensation instead of the year of death. Therefore, we aimed to describe the current state of external-cause mortality and investigate whether there are inequalities in external-cause mortality by industry among Korean workers regardless of recognition for workers' compensation.

2. Materials and methods

2.1. Number of total workers and death cases

In Republic of Korea, the employment insurance system was implemented in 1995, and all workplaces with at least one full-time worker have been subject to mandatory coverage since 1998. Therefore, barring some exceptions, the employment insurance subscriber data can be considered as a representative of the total working population in Republic of Korea. In this study, the number of employment insurance subscribers was considered as the number of total workers. However, the number of subscribers changes every day. Hence, we determined the number of total workers as the number of subscribers on July 1, 2018, as it is the midpoint of a year. As a result, 13,057,433 subscribers were identified, and 12,348,609 workers aged between 20 and 64 years were used as total workers in the analyses.

Death registry data from Statistics Korea and employment insurance data by the Korean Employment Information Service were combined. Among the total death cases that occurred in 2018, everyone who ever subscribed for employment insurance from

1995 to 2018 was selected. As a result, 20,820 cases of external-cause death were identified. Among them, 4,962 cases with death at the age of <20 and ≥ 65 years and 12,212 cases in which death occurred after 90 days from unemployment were excluded. In this study, we defined a worker's death as a death that occurred during the employment period, or a death that occurred within 90 days after unemployment, since most deaths from external causes occur within 90 days, and workers can lose their jobs during hospitalization (between accident and death) [14]. Finally, 3,646 cases of external-cause deaths remained and were included in the analyses.

2.2. General population and number of death cases

Data for the total Korean population of 2018, including the number of deaths by external causes, were obtained from the annual report on the cause of death statistics published by Statistics Korea [3].

2.3. External cause of death

Statistics Korea provides the cause of death according to the International Classification of Diseases codes (10th revision) and categorizes the cause of death into 103 causes according to the condensed list of general mortality suggested by the World Health Organization. The list has one category for the external cause of death (external causes of morbidity and mortality, code: V01–Y89) and eight subcategories: transport accidents (V01–V99), falls (W01–W19), accidental drowning and submersion (W65–W74), exposure to smoke, fire, and flames (X00–X09), accidental poisoning by and exposure to noxious substances (X40–X49), intentional self-harm (X60–X84), assault (X85–Y09), and all other external causes (W20–W64, W75–W99, X10–X39, X50–X59, Y10–Y89). In the analysis, we classified them into three categories: suicide (intentional self-harm), transport (transport accidents), and others (other six subcategories).

2.4. Other variables

We obtained data on sex, age, date of employment insurance subscription and disqualification, and industry classified by the 10th Korean Standard Industrial Classification [15], which is based on the International Standard Industrial Classification of death cases from employment insurance data. Sex and age (five-year intervals from ages of 20–64) were used for standardization, and the date of employment insurance subscription and disqualification was used to determine the inclusion of cases. In addition, education level and average income in 2018 were obtained from a survey by the Ministry of Employment and Labor. The survey investigated 33,000 workplaces that were statistically sampled to represent all workplaces in Republic of Korea. The average income per month was used as a continuous variable, and education level was surveyed into five categories and divided into two groups in this study: high school or less (middle school or less and high school), and college or above (junior college, university, and graduate school) [16].

2.5. Statistical analyses

First, age- and sex-standardized mortality rates per 100,000 were calculated by direct standardization using the entire Korean population of 2018 in five-year age intervals. Further, using the highest and lowest mortality rates by the industry for each cause of death, rate differences were calculated by subtracting the lowest from the highest mortality rate. Second, standardized mortality ratios (SMRs) and 95% confidence intervals (95% CIs) were calculated by indirect standardization using the entire Korean

population of 2018. Additionally, SMRs and 95 CIs were calculated by indirect standardization using total workers as a reference to identify industries with higher risk. Third, mortality rate ratios (RRs) and 95% CIs were estimated by Poisson regression using the information and communication industry as a reference group. The information and communication industry was used as a reference group because age- and sex-standardized external-cause mortality was the lowest among industries with more than 100,000 workers. Lastly, we conducted Spearman's correlation analyses between education level, average income, and mortality to examine correlations between socioeconomic status and mortality. Two industries (public administration and defense, activities of extraterritorial organizations and bodies) were excluded from the correlation analysis due to the unavailability of data. All statistical tests were two-tailed, and p-values less than 0.05 were regarded as statistically significant. All statistical analyses were conducted with the SAS software package version 9.4 (SAS Institute, Cary, NC, USA).

3. Results

The number of workers and number of deaths are presented in Table 1. In 2018, there were 12,348,609 workers, and the number of workers in the manufacturing industry (28.1%) was the highest among all industries, followed by wholesale and retail trade (11.9%). Similarly, deaths among manufacturing workers (30.5%) were the highest among all deaths, followed by wholesale and retail trade (11.5%). Suicide (57.8%) was the most common external cause, followed by transport accidents (20.8%).

Age- and sex-standardized mortality from all external causes was 29.4 per 100,000 workers (Table 1). Cause-specific mortalities were as follows: suicide (16.2), transport accidents (6.6), and others (6.6). When we divided other causes into six subcategories, mortalities per 100,000 were as follows: other external causes (2.6), falls (2.1), drowning (0.7), assault (0.5), poisoning (0.4), and fire (0.3). Mining and quarrying (90.0) and agriculture, forestry, and fishing (48.1) showed the highest mortality. On the contrary, electricity, gas, steam, and air conditioning supply (12.3) and information and communication (16.9) showed the lowest mortality. Analysis of cause-specific mortality showed higher suicide mortalities in mining and quarrying (25.5) and transportation and storage (22.6), higher transport accident mortalities in mining and quarrying (21.3) and agriculture, forestry, and fishing (19.7), and higher mortalities from other external causes in mining and quarrying (43.1). Age- and sex-standardized mortality by industry from all external causes ranged from 12.3 to 90.0, which yielded a rate difference of 77.7. The rate differences in suicide, transport accidents, and others were 17.9, 20.0, and 42.5, respectively.

Table 2 shows SMRs and cause-specific SMRs by industries using an indirect method. Generally, SMRs from all external causes and specific causes for most industries were significantly lower than compared to the Korean general population. In contrast, SMR from all external causes was significantly higher only in the mining and quarrying industry (SMR 3.04, 95% CI 1.74–4.34). Moreover, three industries showed significantly higher SMRs from transport accidents: mining and quarrying (5.91, 1.18–10.63), agriculture, forestry, and fishing (3.55, 1.35–5.76), and public administration and defense (2.40, 1.67–3.14), whereas no industry showed significantly higher SMR from suicide. Additionally, a higher SMR from other external causes was shown in mining and quarrying (5.58, 2.28–8.87).

The results of comparing mortality among industries using the information and communication industry as a reference group are shown in Table 3. The RR from all external causes was the highest in mining and quarrying (RR 9.31, 95% CI 5.19–14.96), followed by agriculture, forestry, and fishing (3.33, 2.09–5.30), and public

administration and defense (3.09, 2.37–4.02). When divided by specific causes, mining and quarrying showed the highest RRs for all causes with 2.91 (1.06–7.97) from suicide, 30.86 (10.33–92.19) from transport accidents, and 18.41 (8.58–39.51) from other causes.

When we calculated SMRs using total workers as a reference, significantly higher SMRs for suicide were shown in transportation and storage (1.58, 1.36–1.80), business facilities management (1.20, 1.03–1.38), and wholesale and retail trade (1.18, 1.04–1.31). Furthermore, significantly higher SMRs for transport accidents were shown in mining and quarrying (6.14, 1.23–11.05), agriculture, forestry, and fishing (3.54, 1.35–5.73), public administration and defense (2.33, 1.62–3.04), transportation and storage (1.54, 1.20–1.88), and construction (1.31, 1.00–1.62) (Table 4).

We found weak to moderate negative correlations between income and mortality and moderate to strong negative correlations between education level and mortality in our correlation analyses (Table 5). When primary industries (agriculture, forestry and fishing, and mining and quarrying) were excluded, the correlation between income and mortality became stronger, but the correlation between education and mortality became weaker. Income and mortality by industry and scatter plots of correlation analyses are available in the supplementary material.

4. Discussion

In this study, we investigated external-cause mortality and its difference by industry in Korean workers for the year 2018. Mortality differences across industries were found, despite mortalities of the workers from external causes being lower than those for the general population. Agriculture, forestry and fishing, and mining and quarrying generally showed high mortalities. Moreover, construction, wholesale and retail trade, business facilities management, and public administration and defense showed higher mortalities for at least one specific cause.

In our study, the total external-cause mortality of workers was 29.4 per 100,000. In a recent study in Japan, external-cause mortality was 25.2 per 100,000 in male workers aged 25–64 [8]. Since the two studies have different inclusion criteria, we calculated crude external-cause mortalities using raw data of the two countries [5]. Including the entire working population regardless of age and sex, and only cases that occurred during employment, mortality of the two countries was similar. In Republic of Korea, external-cause mortality per 100,000 was 21.1 in workers and 54.7 in the total population. In Japan, it was 21.2 in workers and 55.2 in the total population [3]. However, further age and sex standardization is needed for exact comparison.

The SMR from all external causes in workers was significantly lower compared to the general population, mostly due to lower suicide rates in workers. The result is consistent with previous studies reporting a higher risk of suicide in unemployed people [17,18]. There are possible mechanisms explaining this result. One is the effect of mental illnesses such as depression. It is well known that depression is related to an increased risk of suicide [19]. However, people with depression are more likely to leave their job [20], and workers who become unemployed are more likely to develop depressive symptoms [21]. Additionally, unemployment is related to the problematic use of substances, which is also a risk factor for suicide [22].

Meanwhile, there was no significant difference in SMR from transport accidents. Given that workers are more likely to be exposed to the risk of transport accidents due to commute and the use of vehicles in job duties (e.g., occupational drivers or operators of construction vehicles), this result is interesting. Although not clear, the healthy worker effect may have an impact on this result.

Table 1
All and cause-specific external-cause mortality by industry in Republic of Korea, 2018

Industry classification	Total workers		All external-cause death				Cause-specific death											
	N	(%)	N	Rate per 100,000		N	Suicide			Transport			Others					
				Rate per 100,000			Rate per 100,000		Rate per 100,000		Rate per 100,000		Rate per 100,000					
				Crude	Standardized* (95% CI)		Crude	Standardized* (95% CI)	Crude	Standardized* (95% CI)	Crude	Standardized* (95% CI)	Crude	Standardized* (95% CI)				
Agriculture, forestry and fishing	32,442	(0.3)	22	67.8	48.1	((24.6–71.5)	6	18.5	19.7	(1.8–37.6)	10	30.8	15.1	(5.7–24.5)	6	18.5	13.3	(1.4–25.1)
Mining and quarrying	8,957	(0.1)	21	234.5	90.0	(48.2–131.7)	4	44.7	25.5	(0.0–53.7)	6	67.0	21.3	(4.1–38.5)	11	122.8	43.1	(17.5–68.7)
Manufacturing	3,468,129	(28.1)	1,111	32.0	27.5	(25.6–29.4)	615	17.7	14.3	(13.0–15.7)	223	6.4	5.8	(4.8–6.7)	273	7.9	7.5	(6.5–8.5)
Electricity, gas, steam and air conditioning supply	75,843	(0.6)	17	22.4	12.3	(6.0–18.6)	10	13.2	7.7	(2.4–13.0)	6	7.9	4.0	(0.8–7.3)	1	1.3	0.6	(0.0–1.7)
Water supply; sewage, waste management, materials recovery	71,888	(0.6)	42	58.4	39.3	(23.2–55.4)	17	23.6	12.2	(6.3–18.1)	12	16.7	11.5	(2.4–20.6)	13	18.1	15.5	(3.7–27.4)
Construction	658,228	(5.3)	299	45.4	34.2	(28.2–40.3)	157	23.9	17.1	(13.3–20.8)	69	10.5	7.9	(5.2–10.7)	73	11.1	9.2	(5.4–13.1)
Wholesale and retail trade	1,469,391	(11.9)	420	28.6	31.2	(27.8–34.7)	278	18.9	18.9	(16.4–21.5)	73	5.0	6.6	(4.9–8.4)	69	4.7	5.7	(4.2–7.2)
Transportation and storage	567,427	(4.6)	347	61.2	42.0	(35.7–48.4)	199	35.1	22.6	(18.5–26.6)	80	14.1	13.0	(8.4–17.6)	68	12.0	6.5	(4.8–8.2)
Accommodation and food service activities	548,311	(4.4)	155	28.3	34.4	(27.9–40.9)	86	15.7	19.3	(14.5–24.0)	42	7.7	9.1	(5.7–12.4)	27	4.9	6.1	(3.2–8.9)
Information and communication	601,886	(4.9)	95	15.8	16.9	(11.7–22.1)	71	11.8	12.9	(8.0–17.7)	7	1.2	1.3	(0.2–2.4)	17	2.8	2.7	(1.2–4.2)
Financial and insurance activities	471,540	(3.8)	68	14.4	17.0	(9.9–24.2)	47	10.0	7.9	(5.3–10.4)	9	1.9	5.0	(0.0–10.2)	12	2.5	4.2	(0.0–8.3)
Real estate activities	252,311	(2.0)	92	36.5	30.6	(20.8–40.5)	45	17.8	16.9	(9.6–24.2)	17	6.7	4.2	(2.1–6.3)	30	11.9	9.5	(3.2–15.8)
Professional, scientific, and technical activities	703,081	(5.7)	137	19.5	20.6	(15.8–25.3)	85	12.1	12.5	(9.1–15.8)	22	3.1	2.6	(1.5–3.7)	30	4.3	5.5	(2.3–8.7)
Business facilities management and business support services; rental and leasing activities	949,369	(7.7)	290	30.5	31.4	(27.7–35.2)	179	18.9	19.8	(16.8–22.8)	66	7.0	6.9	(5.1–8.6)	45	4.7	4.7	(3.3–6.2)
Public administration and defense; compulsory social security	271,624	(2.2)	134	49.3	46.5	(38.2–54.8)	59	21.7	21.6	(15.7–27.5)	41	15.1	14.0	(9.6–18.4)	34	12.5	11.0	(7.2–14.7)
Education	381,295	(3.1)	59	15.5	21.9	(15.0–28.7)	40	10.5	12.4	(7.9–16.9)	12	3.1	6.5	(2.0–10.9)	7	1.8	3.0	(0.5–5.5)
Human health and social work activities	1,399,262	(11.3)	218	15.6	25.6	(20.6–30.6)	142	10.1	15.1	(11.3–18.9)	35	2.5	4.5	(2.4–6.6)	41	2.9	6.0	(3.5–8.6)
Arts, sports, and recreation-related services	130,664	(1.1)	31	23.7	22.4	(14.1–30.8)	17	13.0	12.3	(6.2–18.4)	8	6.1	6.2	(1.6–10.7)	6	4.6	4.0	(0.6–7.4)
Membership organizations, repair and other personal services	274,647	(2.2)	83	30.2	29.2	(22.7–35.7)	49	17.8	17.4	(12.4–22.5)	20	7.3	6.5	(3.6–9.5)	14	5.1	5.3	(2.5–8.1)
Activities of extraterritorial organizations and bodies	12,314	(0.1)	5	40.6	21.4	(2.5–40.2)	2	16.2	7.6	(0.0–18.2)	1	8.1	3.9	(0.0–11.5)	2	16.2	9.9	(0.0–23.5)
Total	12,348,609	(100.0)	3,646	29.5	29.4	(28.4–30.5)	2,108	17.1	16.2	(15.5–16.9)	759	6.1	6.6	(6.1–7.1)	779	6.3	6.6	(6.1–7.1)
Rate difference [†]				220.1	77.7			34.7	17.9			65.8	20.0		121.5	42.5		

* Age- and sex-standardized mortality by direct standardization method.

[†] Calculated by subtracting the value of the lowest industry from the value of the highest industry.

Table 2
Standardized mortality ratios (SMRs) by industry compared to the general population of Republic of Korea, 2018

Industry classification	External cause of death											
	All external			Suicide			Transport			Others		
	O/E*	SMR	(95% CI)	O/E*	SMR	(95% CI)	O/E*	SMR	(95% CI)	O/E*	SMR	(95% CI)
Agriculture, forestry, and fishing	22/19.5	1.13	(0.66–1.60)	6/11.9	0.51	(0.10–0.91)	10/2.8	3.55	(1.35–5.76)	6/5.2	1.16	(0.23–2.09)
Mining and quarrying	21/6.9	3.04	(1.74–4.34)	4/4.1	0.99	(0.02–1.95)	6/1.0	5.91	(1.18–10.63)	11/2.0	5.58	(2.28–8.87)
Manufacturing	1,111/1,746.1	0.64	(0.60–0.67)	615/1,160.8	0.53	(0.49–0.57)	223/234.3	0.95	(0.83–1.08)	273/380.0	0.72	(0.63–0.80)
Electricity, gas, steam, and air conditioning supply	17/42.1	0.40	(0.21–0.60)	10/27.7	0.36	(0.14–0.58)	6/5.7	1.06	(0.21–1.90)	1/9.5	0.11	(0.00–0.31)
Water supply; sewage, waste management, materials recovery	42/46.6	0.90	(0.63–1.17)	17/28.6	0.59	(0.31–0.88)	12/6.6	1.81	(0.78–2.83)	13/12.2	1.07	(0.49–1.65)
Construction	299/397.0	0.75	(0.67–0.84)	157/254.1	0.62	(0.52–0.71)	69/53.9	1.28	(0.98–1.58)	73/96.1	0.76	(0.59–0.93)
Wholesale and retail trade	420/593.8	0.71	(0.64–0.78)	278/413.8	0.67	(0.59–0.75)	73/74.0	0.99	(0.76–1.21)	69/114.6	0.60	(0.46–0.74)
Transportation and storage	347/371.0	0.94	(0.84–1.03)	199/226.7	0.88	(0.76–1.00)	80/53.1	1.51	(1.18–1.84)	68/98.2	0.69	(0.53–0.86)
Accommodation and food service activities	155/183.3	0.85	(0.71–0.98)	86/127.0	0.68	(0.53–0.82)	42/24.2	1.74	(1.21–2.26)	27/34.4	0.78	(0.49–1.08)
Information and communication	95/257.6	0.37	(0.29–0.44)	71/182.8	0.39	(0.30–0.48)	7/32.0	0.22	(0.06–0.38)	17/46.7	0.36	(0.19–0.54)
Financial and insurance activities	68/202.0	0.34	(0.26–0.42)	47/141.2	0.33	(0.24–0.43)	9/23.8	0.38	(0.13–0.62)	12/40.1	0.30	(0.13–0.47)
Real estate activities	92/152.5	0.60	(0.48–0.73)	45/91.0	0.49	(0.35–0.64)	17/22.5	0.76	(0.40–1.12)	30/41.7	0.72	(0.46–0.98)
Professional, scientific, and technical activities	137/320.8	0.43	(0.36–0.50)	85/217.7	0.39	(0.31–0.47)	22/41.1	0.54	(0.31–0.76)	30/66.9	0.45	(0.29–0.61)
Business facilities management and business support services; rental and leasing activities	290/418.5	0.69	(0.61–0.77)	179/269.0	0.67	(0.57–0.76)	66/58.6	1.13	(0.86–1.40)	45/97.5	0.46	(0.33–0.60)
Public administration and defense; compulsory social security	134/127.3	1.05	(0.87–1.23)	59/81.7	0.72	(0.54–0.91)	41/17.0	2.40	(1.67–3.14)	34/30.7	1.11	(0.74–1.48)
Education	59/123.5	0.48	(0.36–0.60)	40/87.4	0.46	(0.32–0.60)	12/14.1	0.85	(0.37–1.34)	7/23.5	0.30	(0.08–0.52)
Human health and social work activities	218/387.6	0.56	(0.49–0.64)	142/280.3	0.51	(0.42–0.59)	35/41.9	0.83	(0.56–1.11)	41/69.4	0.59	(0.41–0.77)
Arts, sports, and recreation-related services	31/53.7	0.58	(0.37–0.78)	17/36.6	0.46	(0.24–0.68)	8/7.0	1.14	(0.35–1.94)	6/10.9	0.55	(0.11–0.99)
Membership organizations, repair and other personal services	83/122.8	0.68	(0.53–0.82)	49/81.8	0.60	(0.43–0.77)	20/16.1	1.24	(0.70–1.78)	14/26.8	0.52	(0.25–0.80)
Activities of extraterritorial organizations and bodies	5/7.7	0.65	(0.08–1.22)	2/4.7	0.42	(0.00–1.01)	1/1.1	0.91	(0.00–2.69)	2/2.0	0.98	(0.00–2.34)
Total	3,646/5,580.4	0.65	(0.63–0.67)	2,108/3,728.9	0.57	(0.54–0.59)	759/730.8	1.04	(0.96–1.11)	779/1,208.4	0.64	(0.60–0.69)

* Observed number of death/Expected number of death.

As workers are generally healthier than the nonworking population, they are more resilient and more likely to survive in similar accidents. However, there is a need for further investigation into this inference. Nevertheless, industries that frequently use transport vehicles for work (transport and storage, and accommodation and food services) showed significantly higher SMRs. Workers in such industries usually drive heavy vehicles with high risk. The accident rate for commercial freight vehicles is about 5.7 times that of all vehicles, and mortality is almost twice [23]. Moreover, these workers have a higher risk for sleep problems, which induces fatal transport accidents [24].

Although the actual cause of death was relatively small, higher SMR from other external causes in mining and quarrying was notable. Other external causes included falls, drowning, fire, poisoning, assault, and others. However, detailed causes of death in most cases in mining and quarrying were exposure to inanimate mechanical forces, which includes struck by thrown, projected, or falling objects, and caught, crushed, jammed, or pinched in or between objects. This cause of death is usually the result of industrial accidents. A study in the United States also showed a higher

mortality rate from unintentional injuries with 41% excess risk compared to the general population in miners [25]. The result is consistent with the highest fatal industrial accidents observed in the mining industry in workers' compensation in Republic of Korea [11]. In Republic of Korea, most of the mines are located in mountainous and remote rural areas, which are far from large-sized hospitals. Therefore, it takes more time for the workers to get to the hospital when they are injured, and additional time is needed if accidents occur in underground tunnels. Mining is inherently dangerous; however, this geographical situation may have contributed to the results.

When we calculated mortality rate difference using age- and sex-standardized rates, the biggest difference was observed in other external-cause mortality; however, except for mining and quarrying, the differences became similar with mortality difference from suicide and transport accident (15.0 for suicide, 13.8 for transport accidents, and 14.9 for other causes). In our analysis for SMR compared to total workers and mortality, RR also showed considerable inequalities across industries for all specific causes.

Table 3
Mortality rate ratios (RRs) by Poisson regression by industry in Republic of Korea, 2018

Industry classification	External cause of death											
	All external			Suicide			Transport			Others		
	O/E*	RR	(95% CI)	O/E	RR	(95% CI)	O/E	RR	(95% CI)	O/E	RR	(95% CI)
Agriculture, forestry, and fishing	22/6.6	3.33	(2.09–5.30)	6/4.2	1.44	(0.63–3.32)	10/0.6	17.81	(6.76–46.93)	6/1.6	3.65	(1.44–9.30)
Mining and quarrying	21/2.3	9.31	(5.79–14.96)	4/1.4	2.91	(1.06–7.97)	6/0.2	30.86	(10.33–92.19)	11/0.6	18.41	(8.58–39.51)
Manufacturing	1,111/630.1	1.76	(1.43–2.18)	615/444.0	1.39	(1.08–1.77)	223/48.6	4.59	(2.16–9.75)	273/129.4	2.11	(1.29–3.45)
Electricity, gas, steam, and air conditioning supply	17/15.1	1.13	(0.67–1.89)	10/10.6	0.95	(0.49–1.84)	6/1.2	5.11	(1.72–15.23)	1/3.2	0.32	(0.04–2.38)
Water supply; sewage, waste management, materials recovery	42/15.8	2.66	(1.85–3.83)	17/10.2	1.67	(0.98–2.83)	12/1.3	9.20	(3.61–23.42)	13/3.8	3.40	(1.65–7.02)
Construction	299/136.0	2.20	(1.74–2.77)	157/92.3	1.70	(1.28–2.26)	69/10.7	6.45	(2.96–14.07)	73/30.7	2.38	(1.40–4.05)
Wholesale and retail trade	420/215.4	1.95	(1.56–2.44)	278/156.6	1.78	(1.37–2.30)	73/16.4	4.46	(2.05–9.69)	69/10.9	1.69	(0.99–2.87)
Transportation and storage	347/124.6	2.79	(2.22–3.50)	199/79.3	2.51	(1.91–3.30)	80/10.5	7.63	(3.51–16.58)	68/30.8	2.21	(1.29–3.78)
Accommodation and food service activities	155/72.0	2.15	(1.66–2.78)	86/49.8	1.73	(1.26–2.37)	42/6.0	6.96	(3.12–15.54)	27/14.1	1.92	(1.04–3.54)
Information and communication	95/-	1.00	(Reference)	71/-	1.00	(Reference)	7/-	1.00	(Reference)	17/-	1.00	(Reference)
Financial and insurance activities	68/69.6	0.98	(0.72–1.33)	47/51.5	0.91	(0.63–1.32)	9/5.1	1.78	(0.66–4.79)	12/13.2	0.91	(0.43–1.90)
Real estate activities	92/50.7	1.82	(1.36–2.42)	45/30.8	1.46	(1.00–2.13)	17/4.4	3.82	(1.58–9.26)	30/13.2	2.27	(1.24–4.14)
Professional, scientific, and technical activities	137/112.7	1.22	(0.94–1.58)	85/79.9	1.06	(0.78–1.46)	22/8.8	2.51	(1.07–5.88)	30/22.8	1.32	(0.73–2.39)
Business facilities management and business support services; rental and leasing activities	290/148.8	1.95	(1.54–2.46)	179/97.1	1.84	(1.40–2.43)	66/12.7	5.21	(2.38–11.39)	45/33.8	1.33	(0.76–2.34)
Public administration and defense; compulsory social security	134/43.4	3.09	(2.37–4.02)	59/28.8	2.05	(1.45–2.90)	41/3.6	11.53	(5.16–25.78)	34/9.9	3.42	(1.90–6.14)
Education	59/42.5	1.39	(1.00–1.93)	40/30.7	1.30	(0.88–1.93)	12/3.3	3.65	(1.43–9.31)	7/8.2	0.85	(0.35–2.07)
Human health and social work activities	218/133.3	1.64	(1.28–2.09)	142/96.0	1.48	(1.10–1.98)	35/10.4	3.37	(1.48–7.64)	41/25.0	1.64	(0.92–2.92)
Arts, sports, and recreation-related services	31/19.8	1.57	(1.04–2.35)	17/13.8	1.23	(0.72–2.09)	8/1.6	4.99	(1.81–13.78)	6/4.0	1.51	(0.59–3.83)
Membership organizations, repair and other personal services	83/43.6	1.90	(1.42–2.56)	49/30.2	1.62	(1.13–2.34)	20/3.4	5.82	(2.46–13.78)	14/9.2	1.53	(0.75–3.10)
Activities of extraterritorial organizations and bodies	5/2.6	1.95	(0.79–4.79)	2/1.6	1.23	(0.30–5.02)	1/0.2	4.63	(0.57–37.71)	2/0.6	3.13	(0.72–13.56)

* Observed number of death/Expected number of death.

Although included in external causes of death, suicide has a different mechanism to other external causes of death. It is related to sociodemographic and medical factors. Further, it is known to be related to several working conditions such as working hours, employment type, and income [26,27]. It is not clear as to which factors have influenced the increased suicide mortality due to limitations of data. In this study, three industries have shown significantly higher SMRs for suicide compared to total workers (wholesale and retail trade, transportation and storage, and business facilities management). Although many factors are likely to be related to this outcome, higher mortality observed in wholesale and retail trade may be partially explained by the workers' emotional labor and work-related stress [28,29]. Additionally, it is established that the mortality rate from suicide in men is higher than that in women. Therefore, male-dominant industries such as transportation have possibilities for showing higher suicide mortality, consistent with findings from another study with transportation workers [30]. Last, the highest proportion of nonregular workers in business facilities management (70.9%) may have contributed to higher suicide mortality [16].

In contrast, other external causes except for suicide are related to safety. There were five industries with higher transport accident mortality (mining and quarrying, agriculture, forestry, and fishing, public administration and defense, transportation and storage, and construction), and two of them also showed higher other external-cause mortality (mining and quarrying, and public administration and defense). Basically, four industries except for public administration and defense include the use of heavy vehicles as a job duty. Therefore, higher mortalities from transport accidents found in such industries are plausible compared to mortalities from such accidents in other industries. Additionally, higher other external-cause mortality found in mining and quarrying is supported by its dangerous nature and geographical situation, as described above. Meanwhile, public administration and defense showed higher mortalities for both causes. Naturally, this industry category includes workers such as public officers, police, soldiers, and firefighters. However, most of them are subscribers for public official pension or veterans' pension; therefore, they are not subscribers for employment insurance, and hence, were not included in this study. Therefore, they are likely to be contractual or temporary workers in

Table 4
Standardized mortality ratios (SMRs) by industry compared to total workers in Republic of Korea, 2018

	External cause of death											
	All external			Suicide			Transport			Others		
	O/E*	SMR	(95% CI)	O/E*	SMR	(95% CI)	O/E*	SMR	(95% CI)	O/E*	SMR	(95% CI)
Agriculture, forestry and fishing	22/12.6	1.75	(1.02–2.48)	6/6.5	0.92	(0.18–1.65)	10/2.8	3.54	(1.35–5.73)	6/3.2	1.86	(0.37–3.35)
Mining and quarrying	21/4.4	4.76	(2.73–6.80)	4/2.2	1.80	(0.04–3.56)	6/1.0	6.14	(1.23–11.05)	11/1.2	9.08	(3.72–14.45)
Manufacturing	1,111/1,156.4	0.96	(0.90–1.02)	615/674.0	0.91	(0.84–0.98)	223/238.0	0.94	(0.81–1.06)	273/244.4	1.12	(0.98–1.25)
Electricity, gas, steam, and air conditioning supply	17/28.0	0.61	(0.32–0.90)	10/16.2	0.62	(0.24–1.00)	6/5.7	1.04	(0.21–1.88)	1/6.1	0.17	(0.00–0.49)
Water supply; sewage, waste management, materials recovery	42/30.1	1.39	(0.97–1.82)	17/16.1	1.06	(0.56–1.56)	12/6.5	1.84	(0.80–2.89)	13/7.6	1.72	(0.78–2.65)
Construction	299/256.4	1.17	(1.03–1.30)	157/143.8	1.09	(0.92–1.26)	69/52.6	1.31	(1.00–1.62)	73/60.1	1.22	(0.94–1.49)
Wholesale and retail trade	420/390.6	1.08	(0.97–1.18)	278/236.6	1.18	(1.04–1.31)	73/78.0	0.94	(0.72–1.15)	69/75.9	0.91	(0.69–1.12)
Transportation and storage	347/239.5	1.45	(1.30–1.60)	199/126.0	1.58	(1.36–1.80)	80/52.0	1.54	(1.20–1.88)	68/61.6	1.10	(0.84–1.37)
Accommodation and food service activities	155/127.9	1.21	(1.02–1.40)	86/73.5	1.17	(0.92–1.42)	42/30.1	1.40	(0.97–1.82)	27/24.3	1.11	(0.69–1.53)
Information and communication	95/171.7	0.55	(0.44–0.66)	71/107.2	0.66	(0.51–0.82)	7/33.0	0.21	(0.06–0.37)	17/31.5	0.54	(0.28–0.80)
Financial and insurance activities	68/128.4	0.53	(0.40–0.66)	47/79.3	0.59	(0.42–0.76)	9/23.6	0.38	(0.13–0.63)	12/25.5	0.47	(0.20–0.74)
Real estate activities	92/97.5	0.94	(0.75–1.14)	45/48.9	0.92	(0.65–1.19)	17/22.5	0.76	(0.40–1.12)	30/26.1	1.15	(0.74–1.56)
Professional, scientific, and technical activities	137/208.9	0.66	(0.55–0.77)	85/123.4	0.69	(0.54–0.84)	22/41.6	0.53	(0.31–0.75)	30/43.9	0.68	(0.44–0.93)
Business facilities management and business support services; rental and leasing activities	290/275.7	1.05	(0.93–1.17)	179/148.8	1.20	(1.03–1.38)	66/63.4	1.04	(0.79–1.29)	45/63.5	0.71	(0.50–0.92)
Public administration and defense; compulsory social security	134/81.3	1.65	(1.37–1.93)	59/44.5	1.33	(0.99–1.66)	41/17.6	2.33	(1.62–3.04)	34/19.2	1.77	(1.18–2.37)
Education	59/77.4	0.76	(0.57–0.96)	40/46.7	0.86	(0.59–1.12)	12/15.3	0.78	(0.34–1.22)	7/15.3	0.46	(0.12–0.80)
Human health and social work activities	218/238.0	0.92	(0.79–1.04)	142/144.5	0.98	(0.82–1.14)	35/49.5	0.71	(0.47–0.94)	41/43.9	0.93	(0.65–1.22)
Arts, sports, and recreation-related services	31/36.3	0.85	(0.55–1.16)	17/1.1	0.81	(0.42–1.19)	8/7.7	1.03	(0.32–1.75)	6/7.4	0.81	(0.16–1.45)
Membership organizations, repair and other personal services	83/80.1	1.04	(0.81–1.26)	49/46.0	1.06	(0.77–1.36)	20/17.0	1.18	(0.66–1.70)	14/17.1	0.82	(0.39–1.25)
Activities of extraterritorial organizations and bodies	5/4.9	1.02	(0.13–1.91)	2/2.6	0.78	(0.00–1.85)	1/1.1	0.93	(0.00–2.75)	2/1.3	1.58	(0.00–3.76)
Total	3,646/-	1.00	(Reference)	2,108/-	1.00	(Reference)	759/-	1.00	(Reference)	779/-	1.00	(Reference)

* Observed number of death/Expected number of death.

the public area and not regular workers. Nonregular workers' high job insecurity is related to an increased risk of suicide and injuries [26,31]. They also have a reduced chance for receiving education, less support from supervisors or colleagues, and they prioritize

their work over safety, all leading to increased risk for fatal injuries [18,32,33].

In addition, there are some points to be considered when interpreting the mortality in the agriculture, forestry, and fishing

Table 5
Spearman's correlation coefficients between income, education, and external-cause mortality

	Age- and sex-standardized rates (per 100,000) [†]			Standardized mortality ratios compared to general population [‡]		
	All external	Suicide	Transport	All external	Suicide	Transport
18 industries [‡]						
Income	-0.38	-0.45	-0.29	-0.36	-0.49	-0.32
Education	-0.82	-0.61	-0.68	-0.81	-0.74	-0.70
16 industries [§]						
Income	-0.49	-0.55	-0.39	-0.47	-0.55	-0.42
Education	-0.81	-0.55	-0.62	-0.79	-0.72	-0.66

* Calculated using direct standardization method.

† Calculated using indirect standardization method.

‡ Public administration and defense, compulsory social security, activities of extraterritorial organizations and bodies were excluded because data were not available.

§ Agriculture, forestry, and fishing, mining and quarrying were additionally excluded from 18 industries.

industry. Workers in this industry are more likely to belong to low socioeconomic status groups [6,8]. Low socioeconomic status measured by education level and higher transport accident injury mortality may be related, possibly due to the unaffordability of new cars and protective devices [34]. Additionally, more fatal accidents have been reported in rural than urban areas due to more aged drivers, less proportion of drivers using seat belts, and low accessibility to hospitals [35]. Besides, there is a possibility of mortality being underestimated. As data were from employment insurance, self-employed workers were not included in this study. However, many workers in agriculture and fishing are self-employed in Republic of Korea, and self-employed farmers are at a higher risk for injuries than employed farmers due to their unfavorable economic situation to afford protective equipment and reduced chance to receive education on safety and health [36].

The results of our correlation analysis suggest that alongside the hazards of the industry itself, socioeconomic status plays an important role in external-cause mortality inequality. Education level is known to affect health by improving health-related knowledge and acting as a determinant of occupation and income [37]. Given that education level was more strongly correlated to external-cause mortality than income, health-related knowledge can be considered as an affecting factor for mortality inequality. Therefore, providing education on health to improve workers' health-related knowledge may be a way to overcome mortality inequality across industries.

This study has some strengths. First, we used objective data obtained from government agencies. Therefore, there was no bias arising from self-report. Second, the data included all death cases in 2018 and information of industries registered on employment insurance; thereby, the results of this study can be considered as representative of the entire Korean population. In addition, to the best of our knowledge, this is the first study to report on workers' death by industry, regardless of recognition for workers' compensation.

Nevertheless, there are several limitations when interpreting the results of this study. First, this study was based on data of only one year. Therefore, it is unclear whether the results from this study are confined only to the year 2018. Future studies, including data of multiple years and trend analyses, can clarify the general trend of external-cause mortality inequality in Republic of Korea. Second, our study used data from employment insurance, and there are certain kinds of workers who are not eligible for subscription, such as subscribers of special occupation retirement pension (public officers, soldiers, and private school personnel), and workers who work less than 60 h a month (or less than 15 h a week). However, all other workers are obligated to subscribe, and nonsubscribers are concentrated in certain types of industries representing the education and public domains. Therefore, although some bias in the results of public administration and defense was found, in which most nonsubscribers are included, effects on other industries seem minimal. Third, the majority of the workers in agriculture and fishing are self-employed or unpaid familial workers in Republic of Korea. Considering that self-employed farmers are at higher risk for injury or suicide than employed farmers, there is a possibility of underestimation of mortality in agriculture, forestry, and fishing, even though it showed high external-cause mortality. Fourth, our case definition included death that occurred up to 90 days from disqualification of employment insurance. We defined it based on a previous study stating that death from work-related accidents occurred mostly up to 90 days [14], to include as many work-related cases as possible; however, cases unrelated to work may have been included. Nevertheless, the bias arising from the case definition is likely to be a random bias. Therefore, comparison across industries was less likely to be affected. However, the possibility of

overestimation of SMR compared to the general population remains. Fifth, due to a small number of cases in the reference group (information and communication), the results of mortality RR analysis yielded wide CIs and high RRs, which must be interpreted with caution. Finally, education level and income used in our correlation analysis were obtained from a different source to our main dataset. However, as all data were collected by the Korean government, there would be no difference in the macroscopic trend, although some errors in detail are possible.

5. Conclusions

We found inequalities in external-cause mortality across industries in Republic of Korea. Since there were inequalities in all specific causes, measures toward suicide prevention, promoting safe driving, and industrial accidents prevention are needed for the workers in the industries with higher mortalities. In particular, the primary industries, transportation and storage, and public administration and defense should be the main targets.

Ethics statement

The Institutional Review Board of Ajou University Hospital reviewed its protocol and approved this study (AJIRB-MED-EXP-20-239).

Conflicts of interest

None to declare.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at <https://doi.org/10.1016/j.shaw.2021.12.001>.

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