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Injury epidemiology of workers by age, sex and industrial classification using the medical claim data of National Health Insurance in South Korea, 2012–2015: a population-based retrospective study

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ABSTRACT

Objectives This study aimed to evaluate the risk of inpatient hospitalisation for all-cause injuries, according to age, sex and industrial classification (IC) in South Korea.

Design A population-based retrospective study.

Setting and participants Data from the National Health Insurance Database on medical claims for the entire population of South Korean workers aged 25–59 years from January 2012 to December 2015 were retrieved. We observed 30 900 712 person-years (63.1%) in male workers and 18 105 272 person-years (36.9%) in female workers.

Main outcome measures The inpatient hospitalisation for all-cause injury was defined as admission for which the principal diagnosis included S00–T98 in the Korean version of International Classification of Diseases-10 codes.

Results Of 788 575 hospitalisations for all-cause injuries from 2012 to 2015, there were 565 107 cases in male workers (1 828.8 per 100 000 person-years) and 223 468 cases in female workers (1 234.3 per 100 000 person-years). The top five ICs with hospitalisation rate ratios (HRR) for all-cause injuries in both sexes compared with the financial intermediation IC included agriculture, hunting and forestry (HRR (95% CI); male: 2.09 (1.98 to 2.20); female: 1.53 (1.40 to 1.67)); mining and quarrying (male: 2.05 (1.92 to 2.19); female: 1.54 (1.27 to 1.87)) and fishing (male: 1.68 (1.57 to 1.80); female: 1.71 (1.51 to 1.93)). A U-shaped relationship occurred between age and risk for injuries in males; however, only a linear relationship was shown in females, regardless of IC.

Conclusions The risk of injures varied by IC. The workers in agriculture, hunting, forestry, mining, quarrying and fishing were more vulnerable to injuries. The risk for injuries were higher among men and the age effect on this risk differed by sex. Thus, policy makers need to consider specific measures for prevention of injuries according to age, sex and IC.

Strengths and limitations of this study

► The study establishes the relationship between industrial classifications within which workers are employed and the risk for injuries among the entire insured population of employees aged 25–59 years, using data from the whole population database of the National Health Insurance in South Korea.

► The results of the study can inform the age and sex effects on injuries according to industrial classification in South Korea.

► Daily workers whose employment period is less than <1 month are not eligible for employee insured insurance; thus, such workers were excluded from our study.

INTRODUCTION

Injuries are major public health issues with considerable socioeconomic impact. In 2013, 973 million (uncertainty interval (UI) 942–993) and 4.8 million (UI 4.5–5.1) people sustained or died from injuries worldwide, respectively.[1] Occupational injuries account for a considerable proportion of all-cause injuries, especially among the economically active population. Occupational risk factors, according to the WHO Comparative Risk Assessment project, were responsible for 8% of injuries in the year 2000.[2] In South Korea, 89 848 workers required 4 or more days of nursing due to occupational accidents among 18 560 142 workers eligible for occupational accidents compensation insurance in 2017.[3]

In recent years, there has been an increasing amount of literature on age, service year and sex effects on injuries among workers. The risk for admission for fracture increases with age due to osteoporosis, loss of balance and

decreased reaction time in elderly people.[4 5] Associations between new employment and injuries among workers have been uncovered during decades of study in the US mining industry,[6] and for those working as blue collars or apprentices in the non-agricultural private sector.[7] With respect to the effect of sex on injuries, there were significant differences between both sexes in injuries related to motor vehicle trauma[8] and to occupation.[9]

The risk of occupational injuries varies according to the industrial classification. Workers are exposed to their unique hazardous occupational environments depending on what industry type the workers belong to. According to the 2017 annual report of the Korea Occupational Safety and Health Agency (KOSHA), the incidence of industrial accidents per industry per 1000 persons were reported for mining and quarrying (16.94), forestry (1.36), fishing (1.12), construction (0.84), agriculture (0.73), manufacturing (0.61), transport (0.51), storage and communications and financial intermediation (0.04).[3] Given the sizeable socioeconomic costs of injuries among the economically active workers due to absence from work and loss of work capacity, it is necessary to estimate the risk for injuries according to age, sex and industrial classification to create policies to prevent injuries among targeted workers who are vulnerable to injury.

To date, there are few studies that have investigated the patterns of injury risk by age, sex and industry type in South Korea. To address these research gaps, we investigated the risk of inpatient hospitalisation for all-cause injuries identified by S00–T98 codes in the Korean version of International Classification of Diseases (ICD)-10 according to the industrial classification in which workers were employed, using the claim data of employees insured by the National Health Insurance (NHI) in South Korea. Furthermore, we assessed the effect of workers' age and sex on all-cause injuries among workers aged 25–60 years by industrial classification.

METHODS
Overall design
Data were retrieved from claim files of the NHI Database (NHID). The NHI system is a single insurer and provided universal coverage to approximately 98% of the population in the territory of Korea in 2014.[10] The medical billing and claims in NHID were reviewed by a quality assessment system conducted by the Korean Health Insurance Review and Assessment Service (HIRA).[11] HIRA also reviewed whether treatment and examination by medical providers were performed properly at an appropriate level and cost. The insured population in South Korea are classified as employee insured, self-employed insured and medical aid beneficiaries. Employees insured include the workers (payer for insurance premium), the insured person's spouse, direct lineal ascendants, descendants and unmarried brothers or sisters. In this study, we included only workers, aged between 25 and 59 years, who pay for insurance premium, not their dependents.

Korea's retirement age is usually 60 years, and almost all men have compulsory military service for 2 years before 25 years. Of 51 688 103 person-years of workers in the NHI database from 2012 to 2015, 2 682 119 (646 629; 704 151; 637 571 and 693 768 in 2012, 2013, 2014 and 2015, respectively) person-years with missing or masked values of industrial classification were excluded. In all analyses, the numbers of person-years of follow-up were 11 622 968, 12 043 582, 12 488 898 and 12 850 536 person-years in 2012, 2013, 2014 and 2015, respectively.

Industrial classification
To classify the industries, the International Standard Industrial Classification of All Economic Activities (ISIC) was used in our study. The ISIC is used for reporting of statistics according to such industry types internationally to compare statistical data on economic activities. ISIC was first introduced in 1948 by the United Nations and revised periodically.[12] The NHID adopted and has continued to use the previous ISIC Revision (Rev) 3.0.[13] The financial officer of each company where the insured employees work reports the industrial classification of their company to the NHI according to ISIC Rev 3.0. NHID contains the general information, including sex, age (5-year categories), socioeconomic characteristics and industrial classification, if the insured people work. It represents the characteristics of the insured person on January 1 of each year. In our study, the industrial classification of employees was categorised as level 1 of ISIC Rev 3.0 (online supplementary table 1-1). It was assumed that the employee had worked for 1 year (one person-year) at each level 1 of industry classification in which the employee was employed on January 1 of each year.

Cases included
All NHI-insured claims requiring inpatient hospitalisation were identified for calendar years from 1 January 2012 to 31 December 2015. Hospitalisation for injury, poisoning and certain other consequences of external causes (from this point forward called 'all-cause injury') was defined as any kind of admission with principal diagnosis in S00–T98 using the Korean Standard Classification of Diseases (KCD)-7 codes. The KCD-7 code is the Korean version of ICD-10, a medical classification list by WHO. The KCD-7 codes were selected as the principal diagnosis in each hospitalisation which were most demanding and used frequently for treatment and medical examination. The cases included all admissions which covered inpatient, emergency department admissions or short stay, for which healthcare institutions claimed medical expenses in NHI. We included all-cause injuries regardless of whether the injury occurred at the workplace or not.

Statistical analysis
In the descriptive analyses (table 1), we presented categorical variables as numbers and percentages by year. Hospitalisation rates were calculated as total counts of hospitalisation divided by person-years according to the

Table 1 Descriptive statistics of the study population by study variables from 2012 to 2015

Year	2012		2013		2014		2015	
	N=11 622 968		N=12 043 582		N=12 488 898		N=12 850 536	
N	N	%	N	%	N	%	N	%
Sex								
Male	7 457 478	64.2	7 627 463	63.3	7 837 976	62.8	7 977 795	62.1
Female	4 165 490	35.8	4 416 119	36.7	4 650 922	37.2	4 872 741	37.9
Age (years)								
25–29	1 822 264	15.7	1 746 312	14.5	1 704 165	13.6	1 719 966	13.4
30–34	2 063 733	17.8	2 146 211	17.8	2 209 712	17.7	2 176 135	16.9
35–39	1 933 267	16.6	1 951 552	16.2	1 939 308	15.5	1 989 535	15.5
40–44	1 941 678	16.7	2 040 123	16.9	2 103 874	16.9	2 143 306	16.7
45–49	1 611 830	13.9	1 688 018	14.0	1 829 624	14.6	1 936 629	15.1
50–54	1 398 268	12.0	1 517 161	12.6	1 611 516	12.9	1 678 789	13.1
55–59	851 928	7.3	954 205	7.9	1 090 699	8.7	1 206 176	9.4
Industrial classification								
A—agriculture, hunting and forestry	29 025	0.2	31 867	0.3	34 672	0.3	35 856	0.3
B—fishing	16 636	0.1	17 269	0.1	18 200	0.1	18 661	0.1
C—mining and quarrying	14 719	0.1	14 091	0.1	13 817	0.1	13 638	0.1
D—manufacturing	3 376 353	29.1	3 475 266	28.9	3 601 200	28.8	3 674 502	28.6
E—electricity, gas and water supply	84 675	0.7	84 845	0.7	86 037	0.7	86 805	0.7
F—construction	725 944	6.2	741 270	6.2	769 337	6.2	772 942	6.0
G—wholesale and retail trade; repair of motor vehicles, motorcycles and personal and household goods	1 274 723	11.0	1 348 498	11.2	1 443 257	11.6	1 530 854	11.9
H—hotels and restaurants	243 847	2.1	280 340	2.3	328 634	2.6	371 440	2.9
I—transport, storage and communications	595 282	5.1	596 427	5.0	595 943	4.8	583 706	4.5
J—financial intermediation	419 139	3.6	429 673	3.6	434 251	3.5	432 922	3.4
K—real estate, renting and business activities	1 460 983	12.6	1 514 924	12.6	1 546 239	12.4	1 588 618	12.4
L—public administration and defence; compulsory social security	844 684	7.3	850 709	7.1	868 755	7.0	879 361	6.8
M—education	996 031	8.6	1 036 310	8.6	1 041 092	8.3	1 068 274	8.3
N—health and social work	823 269	7.1	876 642	7.3	929 764	7.4	985 660	7.7
O—other community, social and personal service activities	677 336	5.8	706 829	5.9	739 919	5.9	770 718	6.0
P—private households with employed persons	27 164	0.2	25 627	0.2	25 023	0.2	24 037	0.2
Q—extraterritorial organisations and bodies	13 158	0.1	12 995	0.1	12 758	0.1	12 542	0.1

sex, age group, year and industrial classification. The direct method of standardisation of hospitalisation rate was used to adjust for age and sex. For reference, we adjusted the rate to the population of insured employees reported by NHI in 2015[13] (25–29 years, 1 732 065; 30–34 years, 2 151 548; 35–39 years, 2 119 908; 40–44 years, 2 222 646; 45–49 years, 2 115 189; 50–54 years, 1 801 657 and 55–59 years, 1 401 291). We also used Poisson regression, correcting for the ratio of the deviance and the df of 1, due to the presence of an overdispersed response variable.[14]

Furthermore, we used the logarithm of the person-years at risk as the offset to estimate the hospitalisation rate ratio (HRR) for the association between workers' industrial classification and injuries. To establish the effect of age on all-cause injury, we calculated the HRR of workers in each industrial classification, compared with those aged 25–29 years in the financial intermediation industry, by sex. All analyses and all graphical descriptions were conducted using SAS V.9.4 (SAS Institute, Cary, North Carolina, USA) and R V.3.4.4 (R Foundation for Statistical Computing, Vienna, Austria).

Patient and public involvement statement
We used administrative claim data and did not involve patients in this study.

RESULTS
Table 1 shows the yearly characteristics of the population. Of 49 005 984 person-years from 2012 to 2015, there were 30 900 712 person-years (63.1%) from male workers and 18 105 272 person-years (36.9%) from female workers. The top five proportions of level 1 industry classifications in which workers were employed from 2012 to 2015 were 28.8% in manufacturing (14 127 321 person-years); 12.5% in real estate, renting and business activities (6 110 764 person-years); 11.4% in wholesale and retail trade, repair of motor vehicles, motorcycles and personal and household goods (5 597 332 person-years); 8.5% in education (4 141 707 person-years) and 7.4% in health and social work (3 615 335 person-years).

Of 788 575 injuries from 2012 to 2015, inpatient hospitalisations for dislocations, sprains and strains of specified and multiple body regions (254 039 cases; 32.2%) were the most common, followed by fractures of other limbs (203 020 cases; 25.8%), and other injuries of specified, unspecified and multiple body regions (152 098 cases; 19.3%; see online supplementary tables 1-2). Between 2012 and 2015, there were 565 107 all-cause injuries in male workers during 30 900 712 person-years (1 828.8 per 100 000 person-years) and 223 468 injuries in female workers during 18 105 272 person-years (1 234.3 per 100 000 person-years). Figure 1 shows the crude and standardised rates for hospitalisation in insured employees from 2012 to 2015. The hospitalisation rates were standardised using the number of insured employees reported by NHI in 2015. The crude rate per 100 000 person-years ranged from 1187.3 in male workers in the financial intermediation industry in 2012 to 2773.3 in agriculture, hunting and forestry in 2013. Among the female workers, this ranged from 690.8 in the financial intermediation industry in 2012 to 2104.0 in fishing in 2015. The standardised rate per 100 000 person-years ranged between 1204.5 in male workers in the financial intermediation industry in 2012 and 2758.9 in agriculture, hunting and forestry in 2013. In females, there were 765.8 in extraterritorial organisations and bodies in 2012 and 2104.7 in mining and quarrying in 2014.

Table 2 shows the number, hospitalisation rate and adjusted HRR of all-cause injuries by sex. The top five industrial classifications by year-adjusted and age-adjusted HRR in male workers compared with financial intermediation were agriculture, hunting and forestry (HRR=2.09; 95% CI 1.98 to 2.20); mining and quarrying (HRR=2.05; 95% CI 1.92 to 2.19); construction (HRR=1.74; 95% CI 1.68 to 1.81); fishing (HRR=1.68; 95% CI 1.57 to 1.80) and transport, storage and communications (HRR=1.62; 95% CI 1.56 to 1.68). With respect to female workers, the corresponding top five HRRs compared with financial intermediation were fishing (HRR=1.71; 95% CI 1.51 to 1.93); mining and quarrying (HRR=1.54; 95% CI 1.27 to 1.87); agriculture, hunting and forestry (HRR=1.53; 95% CI 1.40 to 1.67); health and social work (HRR=1.52; 95% CI 1.46 to 1.58); and hotels and restaurants (HRR=1.47; 95% CI 1.40 to 1.54).

There was a stronger positive trend between age and all-cause injuries in female workers than in male workers (figure 2). In males, however, a U-shaped relationship was shown between age and hospitalisation for all-cause injuries. The HRRs for all-cause injuries in female workers compared with female workers aged 25–29 years were 0.94 (95% CI 0.91 to 0.96) for ages 30–34, 1.05 (95% CI 1.02 to 1.08) for ages 35–39, 1.27 (95% CI 1.23 to 1.30) for ages 40–44, 1.82 (95% CI 1.77 to 1.87) for ages 45–59, 2.72 (95% CI 2.64 to 2.80) for ages 50–54, 3.11 (95% CI 3.02 to 3.20) for ages 55–59. The HRRs for all-cause injuries of male workers compared with male workers aged 25–29 years were 0.90 (95% CI 0.87 to 0.92) for ages 30–34, 0.87 (95% CI 0.85 to 0.90) for ages 35–39, 0.86 (95% CI 0.84 to 0.89) for ages 40–44, 0.91 (95% CI 0.88 to 0.93) for ages 45–59, 0.97 (95% CI 0.94 to 1.00) for ages 50–54 and 1.01 (95% CI 0.98 to 1.04) for ages 55–59 years. Figure 3 shows the adjusted HRR and 95% CI of all-cause injuries referenced to the 25–29 years of age male and female financial intermediation strata, respectively. A graphical representation of these findings shows the strong linear relationship of all-cause injuries with age in female workers and the U-shaped relationship in male workers, regardless of industrial classification, except agriculture, hunting and forestry; fishing; mining and extraterritorial bodies.

DISCUSSION
In this study based on the population-based claim data of NHI among employees aged 25–59 years employees, we evaluated the relationship between industrial classifications and risk of inpatient hospitalisations for injury, poisoning and certain other consequences of external causes. The top five industries with risk of hospitalisation for all-cause injuries for both sexes included agriculture, hunting and forestry (item code of ISIC: A); fishing (B) and mining and quarrying (C). Other industries among these top five were construction (F), and transport, storage and communications (I) in male employees; and hotels and restaurants (H), and health and social work
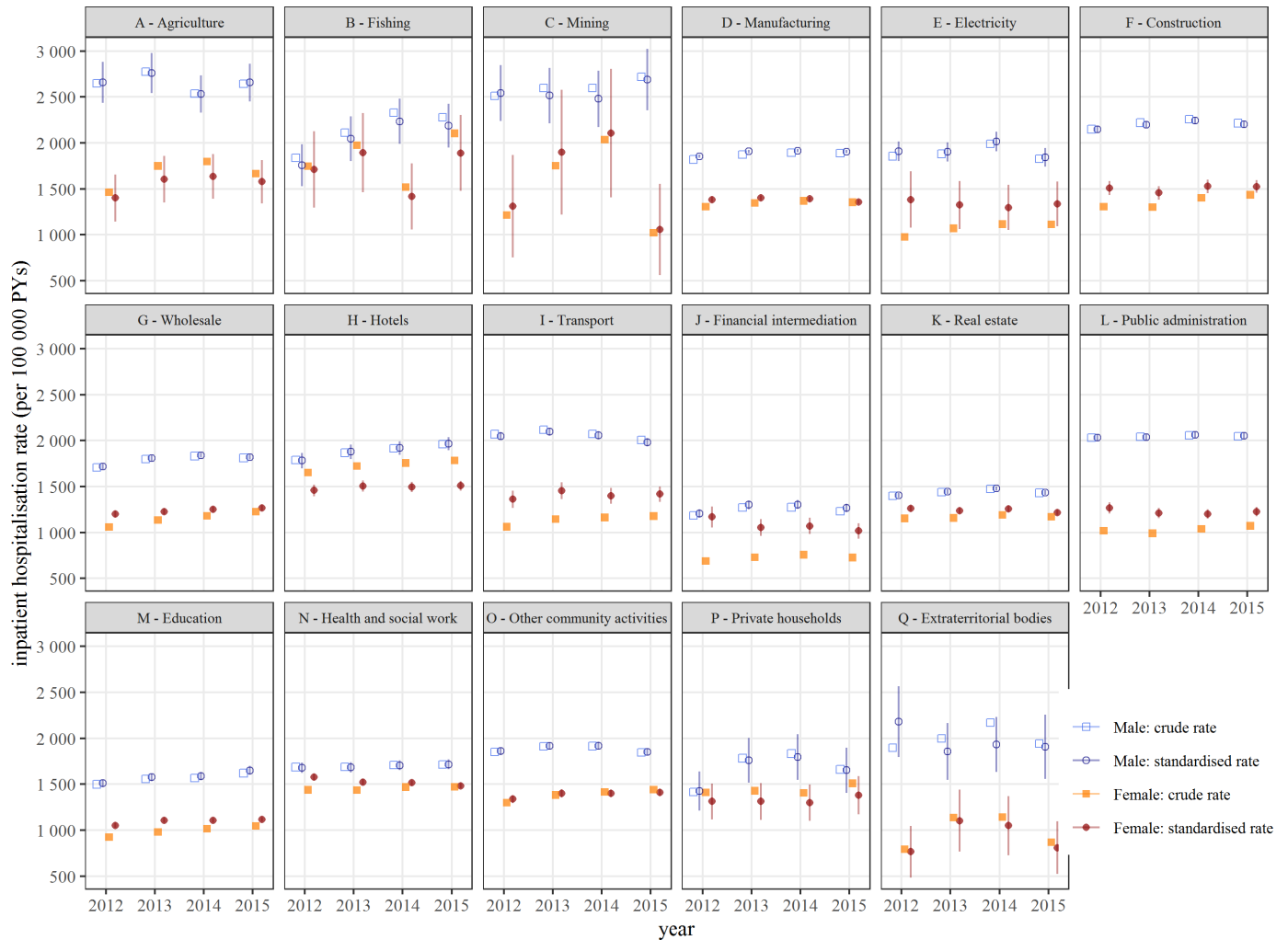
Figure 1 The crude, standardised rate per 100 000 person-years (PYs) and 95% CI of inpatient hospitalisation for all-cause injuries according to the industrial classification for workers aged 25–59 years in South Korea, 2012–2015. The standardised rate of hospitalisation for injury, poisoning and certain other consequences of external causes (S00–T98) was referenced for the population of insured employees reported by the National Health Insurance in 2015 (25–29 years of age, 1 732 065; 30–34 years of age, 2 151 548; 35–39 years of age, 2 119 908; 40–44 years of age, 2 222 646; 45–49 years of age, 2 115 189; 50–54 years of age, 1 801 657 and 55–59 years of age, 1 401 291). The industrial classification titles in the grey box of the figure are not the full names of the level 1 International Standard Industrial Classification of All Economic Activities (full names are shown in the online supplementary table 1-1).

(N) in female employees. These results were consistent with the 2017 Annual Survey of Occupational Injuries and Illnesses in the USA,[15] which showed that agriculture, forestry, fishing and hunting (5.0 per 100 full-time equivalent workers) had the highest incidence of occupational injuries. It was also consistent with the 2017 KOSHA annual report, which showed that the top five industries with the highest incidence were mining and quarrying; forestry, fishing, construction, and agriculture.[3]

It is well established from previous studies that workers in agriculture, hunting and forestry, mining and quarrying and fishing are exposed to a hazardous occupational environment and are vulnerable to injuries. In a study among male workers in agriculture born between 1933 and 1977 in England and Wales, 3238 (30%) of 10 765 participants reported at least one occupational accident from age 14 to 64 years, mainly due to handling,

lifting or carrying (4.9/1000 person-years), falls from a height (4.6/1000 person-years) or injury by animals (3.4/1000 person-years).[16] Historically, mines are considered the most hazardous work environments worldwide. In a cohort study of 56 576 male workers in the nickel industry employed for a cumulative minimum of 6 months in southern Ontario, Canada, the workers in mining had a higher risk of injury and death than the general population in the Province of Ontario (standardised mortality ratio=162; 95% CI 153 to 171).[17] High non-fatal and fatal injuries in miners were partly attributable to handling of non-powered hand tools and carrying heavy materials (eg, off-road ore haulage).[18] With fishing, a retrospective study of 440 355 fishermen-years at risk based on official mortality files in Great Britain revealed that the fatal accident rate was 103.1 per 100 000 fishermen-years from 1976 to 1995. This was 52.4 times higher (95% CI 42.9 to

Table 2 The number of hospitalisation events, crude hospitalisation rates, adjusted rate ratios for all-cause injuries and 95% CI in insured employees aged 25–59 years by sex

	Male				Female			
	Number of events	Person-year	Hospitalisation rate* (/100 000)	Adjusted rate ratio† (95% CI)	Number of events	Person-year	Hospitalisation rate* (/100 000)	Adjusted rate ratio† (95% CI)
Year								
2012	132 970	7 457 478	1783.0	0.97 (0.95 to 0.99)	49 170	4 165 490	1180.4	0.98 (0.95 to 1.00)
2013	140 107	7 627 463	1836.9	1.00 (0.98 to 1.02)	53 836	4 416 119	1219.1	0.99 (0.97 to 1.01)
2014	145 572	7 837 976	1857.3	1.01 (0.99 to 1.03)	58 533	4 650 922	1258.5	1.00 (0.98 to 1.02)
2015	146 458	7 977 795	1835.8	1.00 (ref)	61 929	4 872 741	1270.9	1.00 (ref)
Age (years)								
25–29	72 230	3 746 508	1927.9	1.00 (ref)	26 539	3 246 199	817.5	1.00 (ref)
30–34	94 347	5 415 919	1742.0	0.90 (0.87 to 0.92)	24 149	3 179 872	759.4	0.94 (0.91 to 0.96)
35–39	87 547	5 147 987	1700.6	0.87 (0.85 to 0.90)	22 423	2 665 675	841.2	1.05 (1.02 to 1.08)
40–44	91 810	5 307 718	1729.7	0.86 (0.84 to 0.89)	29 798	2 921 263	1020.0	1.27 (1.23 to 1.30)
45–49	82 682	4 480 878	1845.2	0.91 (0.88 to 0.93)	37 899	2 585 223	1466.0	1.82 (1.77 to 1.87)
50–54	80 157	4 040 661	1983.8	0.97 (0.94 to 1.00)	48 079	2 165 073	2220.7	2.72 (2.64 to 2.80)
55–59	56 334	2 761 041	2040.3	1.01 (0.98 to 1.04)	34 581	1 341 967	2576.9	3.11 (3.02 to 3.20)
Industrial classification								
A—agriculture, hunting and forestry	2463	93 000	2648.4	2.09 (1.98 to 2.20)	645	38 420	1678.8	1.53 (1.40 to 1.67)
B—fishing	1170	54 466	2148.1	1.68 (1.57 to 1.80)	299	16 300	1834.4	1.71 (1.51 to 1.93)
C—mining and quarrying	1280	49 155	2604.0	2.05 (1.92 to 2.19)	107	7110	1504.9	1.54 (1.27 to 1.87)
D—manufacturing	199 128	10 653 131	1869.2	1.50 (1.45 to 1.56)	46 703	3 474 190	1344.3	1.36 (1.30 to 1.42)
E—electricity, gas and water supply	5605	296 924	1887.7	1.51 (1.44 to 1.57)	487	45 438	1071.8	1.25 (1.13 to 1.37)
F—construction	55 464	2 508 561	2211.0	1.74 (1.68 to 1.81)	6831	500 932	1363.7	1.46 (1.40 to 1.54)
G—wholesale and retail trade; repair of motor vehicles, motorcycles and personal and household goods	62 698	3 503 933	1789.4	1.42 (1.37 to 1.48)	24 197	2 093 399	1155.9	1.23 (1.18 to 1.29)
H—hotels and restaurants	10 167	537 327	1892.1	1.49 (1.43 to 1.56)	11 925	686 934	1736.0	1.47 (1.40 to 1.54)
I—transport, storage and communications	40 451	1 957 085	2066.9	1.62 (1.56 to 1.68)	4716	414 273	1138.4	1.34 (1.27 to 1.40)
J—financial intermediation	12 455	1 003 308	1241.4	1.00 (ref)	5184	712 677	727.4	1.00 (ref)
K—real estate, renting and business activities	54 239	3 775 673	1436.5	1.14 (1.10 to 1.18)	27 276	2 335 091	1168.1	1.23 (1.18 to 1.29)
L—public administration and defence; compulsory social security	51 082	2 498 719	2044.3	1.62 (1.56 to 1.68)	9741	944 790	1031.0	1.18 (1.13 to 1.24)
M—education	20 002	1 281 044	1561.4	1.24 (1.19 to 1.29)	28 408	2 860 663	993.1	1.09 (1.04 to 1.13)
N—health and social work	15 291	898 621	1701.6	1.34 (1.29 to 1.40)	39 520	2 716 714	1454.7	1.52 (1.46 to 1.58)
O—other community, social and personal service activities	32 008	1 700 895	1881.8	1.49 (1.44 to 1.55)	16 569	1 193 907	1387.8	1.38 (1.32 to 1.44)
P—private households with employed persons	869	52 139	1666.7	1.30 (1.21 to 1.40)	715	49 712	1438.3	1.31 (1.20 to 1.42)
Q—extraterritorial organisations and bodies	735	36 731	2001.0	1.58 (1.45 to 1.71)	145	14 722	984.9	0.92 (0.78 to 1.09)

*Hospitalisation rate is counts of inpatient hospitalisations divided by person-years in each stratum per 100 000 person-years.
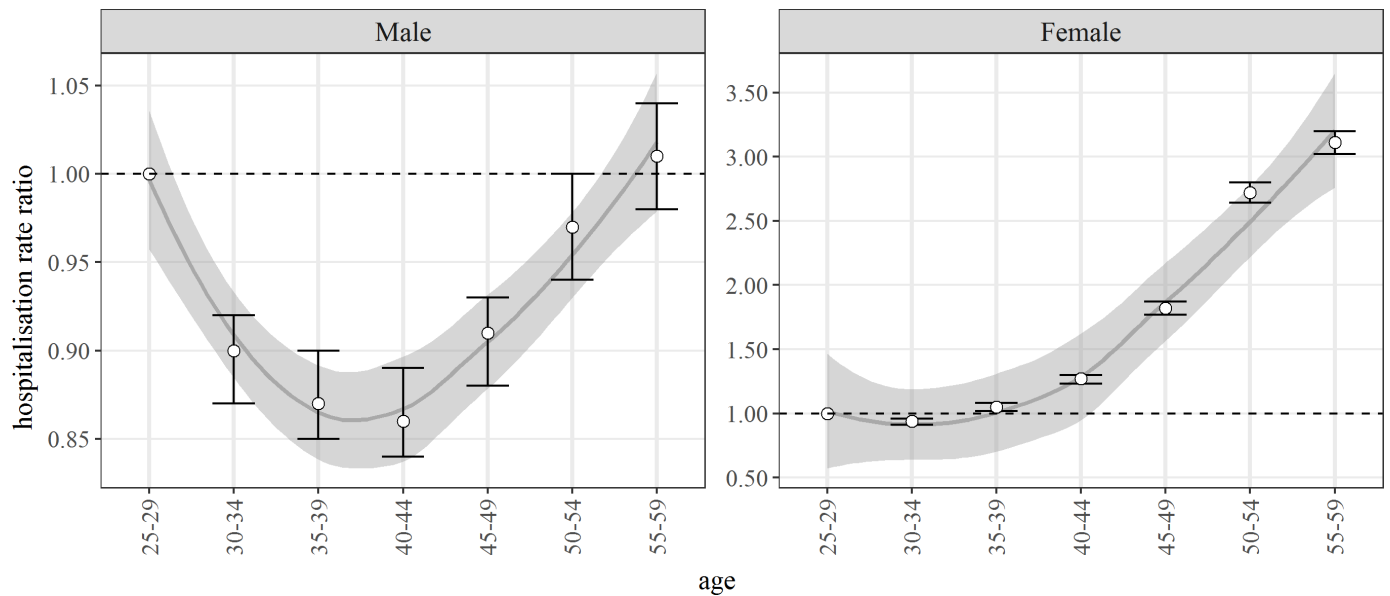†Adjusted rate ratio is hospitalisation rate ratio for all-cause injuries adjusted for year and age.

Figure 2 The adjusted hospitalisation rate ratios (HRR), 95% CI of hospitalisation for all-cause injuries and trends for workers aged 25–59 years in South Korea, 2012–2015. The age and year adjusted HRR for each stratum was compared with those of the employees aged 25–29 years, by sex, respectively. The dark grey line indicates the smooth non-parametric curve using a loess smoother (the loess span 1.00) and the grey shadow indicates the 95% CI of smooth curve.

63.8) than all workers in Great Britain during the same period.[19] A study on the work-related injuries admitted to hospitals in New Zealand's Midland Trauma System from 2012 to 2015 revealed that workers in agriculture/forestry/fishing had the highest risk for injuries among industrial types (agriculture/forestry/fishing 564.5 per 100 000 workers; manufacturing: 426.3 per 100 000 workers; transport/postal/warehousing: 294.9 per 100 000 workers; construction: 275.5 per 100 000 workers).[20]

One interesting finding in our study was the sex-associated difference in age trend in terms of the risk of injuries. A U-shaped relationship was found between age and risk for injuries in males aged 25–59 years and a linear relationship was found in females aged 30–59 years (regardless of industrial classification). Two factors a) protective effects from long period of employment and b) the harmful effects from increased age on the risk of injuries could explain these relationships. With respect to the protective effect from a long career, a number of studies have postulated that injuries occur more frequently in people with shorter career experiences.[18 21] Temporary workers showed a rate ratio of 2.94 (95% CI 2.40 to 3.61) for non-fatal occupational injuries and 2.54 (95% CI 1.88 to 3.42) for fatal occupational injuries compared with permanent workers, which might be mediated through length of employment.[21] However, in our study, the age effects surpassed the protective effect from career experiences, with better knowledge of work and experience, in males aged 55–59 years and females aged 35–39 years. It is now well established from a variety of studies that the risk of fracture increases with age. In a study based on a population of about 42 million people in Kanto, Japan, the annual rate per 1000 person-years was 1.29 among those aged 20–39 years, 2.13 among those aged 40–64 years and 5.22 among those aged 65–79

years.[22] The risk of fracture in the older age groups was greater in females than in males (male, 40–64 years, 2.06; 65–79 years, 2.93; females, 40–64 years, 2.19; 65–79 years, 7.28).[22] The risk of osteoporosis increases with age, resulting in an increase of hospitalisation from injuries due to susceptibility to fracture.[4] Especially for women, menopause increases fracture risk in old workers. Menopause results in an oestrogen decrease, which functions as a key regulator of skeletal growth and maturation through decrease in osteoclast formation and activity and increase in osteoblast formation, differentiation and proliferation.[23] In the Women's Health Initiative Clinical Trial cohort, women younger than 40 years at menopause had a higher risk of any fracture than women who were aged ≥50 years at menopause (HR 1.36; 95% CI 1.11 to 1.67).[24] In addition, loss of balance, weak muscle strength and decreased reaction time also increases the risk of hospitalisation due to injuries in older workers.[5] Another possible explanation of age effects on injuries is the effect of gender norms in South Korea. A break in a women's career due to pregnancy and childbirth might induce the lack of protective effects from career experiences in women of childbearing age. In Korean culture where mothers' and wives' roles have been preserved as the fundamental duty of women, although weakened nowadays, career interruptions due to child care occurs mainly among women.[25] This career break and re-employment in unfamiliar occupations could increase the risk of injury for women. These gender (cultural roles) and sex (biological) differences support our current results.

We used the medical claim data of NHI, instead of data on worker's compensation insurance, which is known to be a better representation of occupational injuries. However, the workers' industrial accident compensation database might not include all occupational injuries in
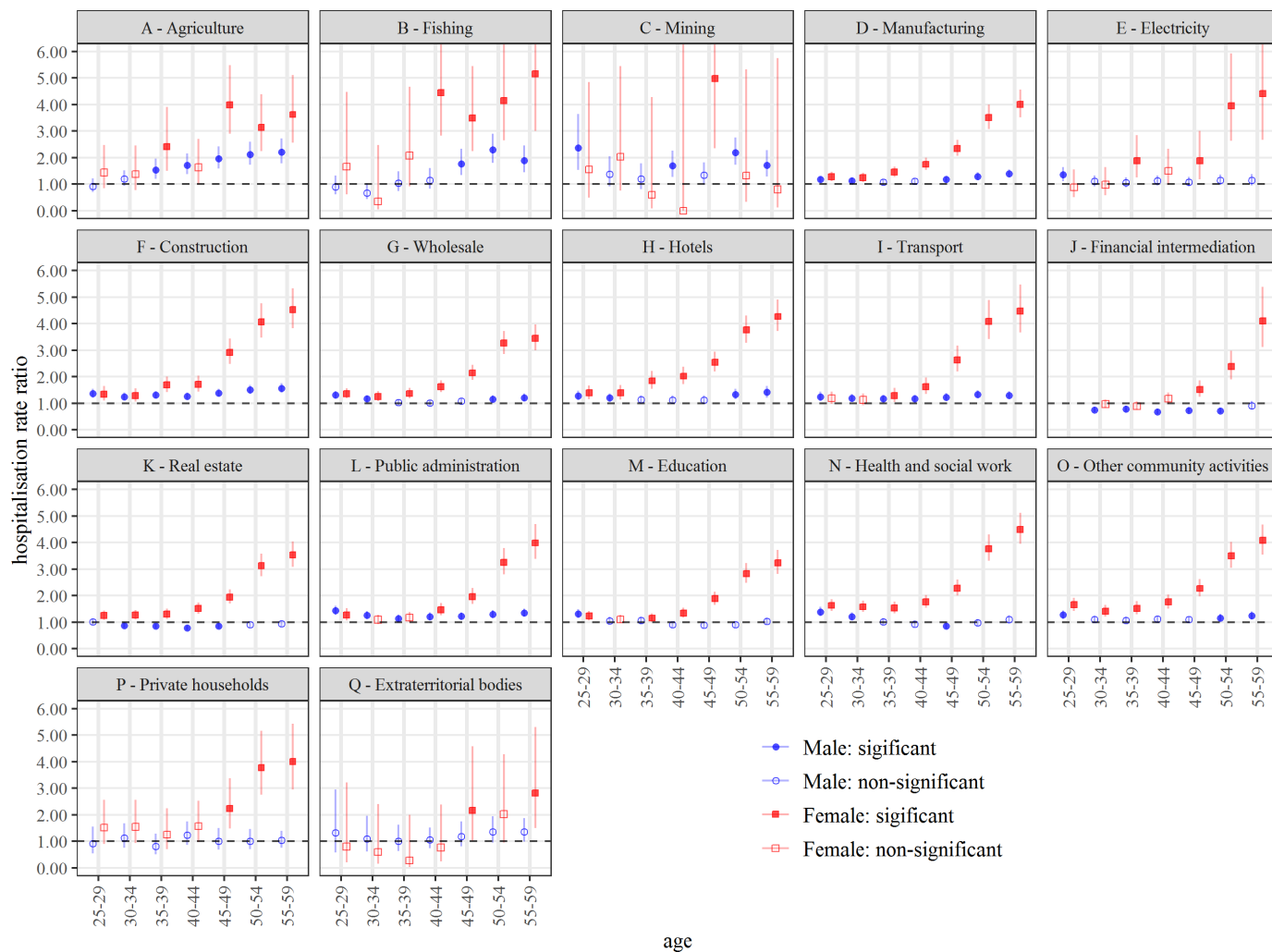
Figure 3 The year-adjusted and age-adjusted hospitalisation rate ratio (HRR) and 95% CI of hospitalisations for all-cause injuries according to industrial classification, 2012–2015. The age-adjusted and year-adjusted HRR for each stratum was compared with that of the employees aged 25–29 years insured in the financial intermediation, by sex, respectively; The industrial classification titles in the grey box of figure are not the full names of the level 1 International Standard Industrial Classification of All Economic Activities (the full names are shown in online supplementary table 1-1).

South Korea. KOSHA has only reported occupational injuries requiring >3 days of medical treatment and that are eligible for compensation benefits.[3] Thus, injuries requiring ≤3 days of medical treatment are not reported. Furthermore, the employers are not obliged to report the occupational injuries to authorities if the cost of the worker's injury is paid directly by employer up until 2014 when a law on employer reporting of industrial accidents was put into place. Previous ecological studies among countries revealed that there may be under-reporting of occupational injuries, especially non-fatal occupational injuries.[26 27] In addition, injuries caused by commuting accidents and injuries in daily life by job-related life-style behaviours, fatigue or psychological and physical problems were not reported in the database of worker's compensation insurance, although these injuries resulted from indirect effects of workers' jobs. In the GAZ and ELectricité (GAZEL) cohort which included 20 625 workers over a 12-year period (1989–2001), self-reported work fatigue was associated with at-work crashes in both

sexes of workers and crashes while commuting among female workers.[28]

To our knowledge, this is the first study to establish the relationship between age, sex and industrial classifications in which workers are employed and the risk of hospitalisation for injuries, using data from the whole population database of NHI in South Korea. We conducted our analysis using qualified data from NHID. The NHI system is a single insurer in South Korea and is reviewed by a quality assessment system in HIRA.[11] HIRA, a government-affiliated quality assessment agency, reviewed all the medical claims provided in the NHI system. However, our results should be interpreted within the context of the study's limitations. First, the injuries reported in our study included occupational injuries and leisure-time injuries. We assumed that leisure-time injuries were not significantly different across the industrial type. Nevertheless, the differences in the non-work exposures may explain the differences observed in our study. However, the average working time of Korean workers is longer than

in other Organisation for Economic Co-operation and Development (OECD) countries. Average annual hours worked was 2084 hours in South Korea and 1751 hours in OECD countries in 2015.[29] Therefore, it is likely that the proportion of injuries might be more related to occupation in South Korea than in other countries. By studying all the injuries of workers regardless of the cause, the results of our research might contain the indirect effect of occupation such as traffic accidents or accidents due to carelessness caused by fatigue or physical and mental problems, or job-related lifestyle behaviours resulting from the workplace. Second, workplace industry classification in which employees are employed is categorised by the financial officers of each company. In addition, daily workers whose employment period is <1 month are not eligible for employee insured insurance, resulting in the exclusion of these workers from our study. However, the number of permanent employees in labour force survey of the Ministry of Labor[30] was not much different from the number of insured employees according to the industrial classification of this study in 2015 (mining and quarrying: 13 282 (labour force survey) vs 13 638 (NHI); manufacturing: 3 453 127 vs 3 674 502; construction: 810 210 vs 772 942; financial intermediation: 446 765 vs 432 922; others are shown in online supplementary tables 1-3). Third, it is assumed that a worker worked for 1 year in the industrial classification based on their employment on January 1 of each year. However, workers in vulnerable occupations such as temporary/daily employees might not have worked for 1 year, and are likely to change jobs. In addition, deceased workers in each year could not have completed 1 year of employment, although the mortality rate under 59 years is not high. These limitations might lead to biassed results in our study, but the exclusion of vulnerable employment in industrial classification might result in underestimation of the risk of injuries in industrial classification characterised by high proportions of vulnerable employment. Fourth, identification of injuries based on the KCD-7 in the NHI database might induce outcome misclassification. With respect to outpatient hypertension diagnoses, medical claim data have a low sensitivity (43%) and relatively high specificity (61%).[31] Although the method of outcome selection using claim data for inpatient visits in our study could bring about accuracy of validated outcome, this misclassification of an outcome might still exist, resulting in biassed results. Fifth, we excluded the young adults aged under 25 years because almost all Korean men aged 20–22 years join the army and perform military service for about 2 years. This exclusion might underestimate the age effects on injuries among young adults. Sixth, because of the limitation of the NHI database, it was not possible to identify important occupational factors, such as the years of employment, shift work and overtime which are associated with risk of injuries.[32] Additional longitudinal studies based on the NHI database, with the data from the labour survey or industrial compensation data are needed to establish the risk of injuries according to industrial classification.

In summary, we reported the risk of injuries according to the level 1 of ISIC using the large, nationwide representative data of NHI in South Korea from 2012 to 2015. In-depth analyses of sex and age stratification showed that effect of age on risk of injury differed by sex of worker. Policy makers need to establish a priority of injury prevention for industrial classification, characterised by vulnerability to injuries with consideration for the age and sex of workers.

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