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# Estimate of the prevalence and burden of food poisoning by natural toxic compounds in South Korea

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A B S T R A C T

Many studies have attempted to accurately estimate the overall number of cases of foodborne illness, but there have not been many attempts to estimate the burden of foodborne disease caused by natural toxic compounds. This study estimated the number of cases due to specific natural toxins (seafood toxins, plant toxins, and mycotoxins) during 2008–2012 in South Korea, using data from the Health Insurance Review and Assessment Service (HIRA), while accounting for uncertainty in the estimate. The estimated annual occurrences of foodborne illness from natural toxic agents were 1088 (90% credible interval [CrI]: 883–1315), which suggests there are 21 times more cases than are reported, with 45.6% ($n = 496$ [388–614]) and 54.4% ($n = 592$ [423–790]), accounting for inpatient stays and outpatient visits, respectively. Among toxins, mushroom and plant toxins caused the highest illnesses, followed by toxic agents in seafood and mycotoxins. The 55–59 year olds had the highest proportion of illnesses and those over the age of 40 accounted for 70.6% of all cases. The cases caused by mushroom poison, poisonous plants, and seafood toxins showed clear seasonal and regional differences. These results will be useful to food safety policymakers for the prevention and control of natural food poisons in South Korea.



## 1. Introduction

Foodborne illness can occur in a variety of ways and is a global public health concern. The etiology of foodborne illnesses consists of more than 250 causes, including a variety of bacteria, viruses, parasites, natural toxins, chemical agents, metals, and prions that may contaminate food and cause foodborne illness (Linscott, 2011).

In particular, foodborne illness caused by natural toxins (e.g. seafood toxins, plant toxins, and mycotoxins) increased in prevalence as temperatures rose worldwide due to climate change during the last decade (Tirado, Clarke, Jaykus, McQuatters-Gollop, & Frank, 2010). In South Korea, an epidemiological study conducted by the Korea Ministry of Food and Drug Safety (KMFDS) showed that outbreaks caused by natural toxins have gradually increased from 0.7% (2008) to 2.1% (2010) (KMFDS, 2014). In addition, from 1998 to 2008 in the United States, the Center for Disease Control and Prevention (CDC) received reports that natural toxins, such as ciguatoxin, mycotoxins, neurotoxic shellfish poison, paralytic shellfish poison, plant/herbal toxins, scombroid toxin/histamine, and others, accounted for 4.1% (554/13,405) of foodborne disease outbreaks, resulting in 0.9% (2350/273,120) of illnesses, 2.5% (231/9109) of hospitalizations, and 2% (4/200) of deaths (Gould et al., 2013).

Several attempts by different countries have been made to estimate foodborne illness at a national level (e.g. Hall et al., 2005; Park et al., 2015; Scallan et al., 2011). However, despite intensive investigations, neither the identification of the responsible agents nor the estimation of foodborne illnesses was appropriately performed owing to the lack of timely reporting, lack of resources for investigations, and other priorities in health departments (WHO, 2011). It is very difficult to determine the exact mortality associated with foodborne illnesses, which are underestimated by public health surveillance systems because of underdiagnosis and underreporting (Lynch, Tauxe, & Hedberg, 2009; MacDougall et al., 2008). Nevertheless, the study of estimates of foodborne illness is very important for national public health decision-making (Greig & Ravel, 2009).

Moreover, the surveillance systems of most countries, including South Korea, only estimate foodborne illness related to food-poisoning microorganisms, such as parasites and viruses; they do not estimate those related to seafood toxins, plant toxins, or mycotoxins. Therefore, the aim of this study was to estimate the actual number of cases and hospitalizations due to specific seafood toxins, plant toxins, and mycotoxins commonly transmitted by contaminated food from 2008 to 2012 in South Korea.

## 2. Methods

### 2.1. Data on food-poisoning cases caused by natural toxic compounds

Data regarding the incidence of food poisoning caused by natural toxic and chemical agents were obtained from the Health Insurance Review and Assessment Service (HIRA, 2013) for the years 2008–2012. We

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used these data because HIRA reviews medical fees and evaluates the appropriateness of medical benefits provided to all South Korean patients (HIRA, 2014). From this data set, cases in which natural toxic and chemical agents had been diagnosed were collected using the Korean Standard Classification of Diseases (Korea Standard Statistical Classification, 2014), which is highly similar to the World Health Organization's International Classification of Diseases, 10th Revision (ICD-10, 2010 update). The ICD-10 assigns numeric codes to specific illnesses to standardize diagnostic criteria for epidemiological, health management, and clinical purposes (WHO, 2010). Nine ICD-10 codes define natural toxic and chemical compounds: T61.0, T61.1, T61.2, T61.8, T61.9, T62.0, T62.1, T62.2, and T64 (Table 1). The collected cases related to natural toxic and chemical agents were then grouped monthly according to inpatient stays (i.e., hospitalizations) and outpatient visits.

### 2.2. Data analysis and simulation for uncertainty

Because HIRA data are only collected from the patient's initial medical examination, we used the method by Park et al. (2015), which considered diagnostic specificities and sensitivities for diagnostic accuracy in South Korea, to ensure diagnostic accuracy for the collected number of patients. Additionally, Project Evaluation and Review Techniques (PERT) distributions were applied to the ranges (5th and 95th percentiles) to account for uncertainty, and to the most likely values using a 90% credible interval (CrI), which were calculated using the method of Park et al. (2015), for the proportions of diagnostic specificities and sensitivities (Fig. 1).

As shown in Fig. 1, the estimated annual number of inpatient stays and outpatient visits caused by natural toxins were obtained by multiplying PERT distributions corresponding to the diagnostic specificity and sensitivity to the number of inpatients and outpatients extracted from the HIRA data. The final estimates were generated using Monte Carlo simulation by @RISK6 software (Palisade, Newfield, NY) according to the method of Park et al. (2015). Uncertainty in the data was accounted for by the 5th and 95th percentile values (i.e., 90% credible interval [CrI]) from the simulation results following previously published methods (Park et al., 2015; Scallan et al., 2011).

## 3. Results

The 5-year annual average number of cases reported in HIRA from 9 natural toxic and chemical agents (9 ICD-10 codes) in South Korea from 2008 to 2012 was 1763 ± 397, with inpatient hospital stays and outpatient hospital visits estimated at 656 ± 123 and 1106 ± 276, respectively (Table 1). From these data and using the method presented in Fig. 1, food-poisoning cases caused by natural toxic and chemical agents were estimated at 1088 (90% CrI: 883–1315), with 45.6% ($n = 496$ [90% CrI: 388–614]) and 54.4% ($n = 592$ [90% CrI: 423–790]), accounting for inpatient stays and outpatient visits, respectively.

As shown in Table 1, an estimated 530 cases (90% CrI: 458–600) were caused by toxic agents in seafood (T61.0, T61.1, T61.2, T61.8, T61.9) (48.7%), 554 cases (90% CrI: 362–770) were caused by mushroom and plant toxins (T62.0, T62.1, T62.2) (50.9%), and 5 cases (90% CrI: 1–8) by mycotoxins including aflatoxin (T64.0) (0.5%).

The leading causes of hospitalizations were "other fish and shellfish poisoning" (T61.2) (54.2%), followed by "other ingested (parts of) plant(s)" (T62.2) (49.9%) and scombroid (histamine-like) fish poisoning (T61.1) (39.8%). Of the 4.4 cases of total natural toxin foodborne illnesses per 100,000, "other fish and shellfish poisoning" (T61.2) was the leading individual cause of illness (0.7 cases), followed by mushroom toxins (T62.0) (0.6 cases), and "other ingested (parts of) plant(s)" (0.5 cases) (Table 2).

According to the distribution of cases by age, the 55–59 year's age group had the highest rate of disease by seafood and plant toxins (Fig. 2 [A], [B]), whereas those over the age of 40 accounted for 70.6% of all cases (Fig. 2 [D]). In most cases, no significant monthly differences occurred, but the cases caused by mushroom poisons (T62.0) and poisonous plants (T62.2) showed clear seasonal differences; mushroom poisons and poisonous plants were higher in September and in the spring, respectively (Fig. 3 [B], [C]). According to the distribution of cases by region, the southern sea areas had a higher number of cases caused by seafood toxins than other regions (Fig. 4), but there were no clear differences between the locally occurring cases caused by mushroom or plant toxins and mycotoxins.

## 4. Discussion

We estimated the national incidence of foodborne illness by natural toxic and chemical compounds (seafood toxins, plant toxins, and mycotoxins) during 2008–2012 in South Korea using data collected from cases reported to HIRA. The estimated annual number of foodborne illness cases caused by 9 natural poison agents in South Korea was a total of 1088, including 496 inpatient stays and 592 outpatient visits, between 2008 and 2012 (Table 1). However, according to the KMFDS reports, there were 4 foodborne disease outbreaks affecting a mean of 52 individuals per year caused by natural poison agents during the same period (KMFDS, 2014). The estimated total number of food-poisoning cases caused by natural toxins was approximately 21 times the reported number.

The KMFDS's reported figure only accounts for cases identified and reported in South Korea. Generally, it seems that individuals intoxicated

**Table 1**
Health Insurance Review and Assessment Service-reported cases and simulation-estimated annual numbers of food poisoning cases caused by natural toxic and chemical agents in South Korea, 2008–2012.

| Natural toxic and chemical agents (ICD-code) | | HIRA reported cases (mean ± SD) | | Estimated cases by caused natural toxic agents (mean (5th − 95th percentile)) | | |
|---|---|---|---|---|---|---|
| | | No. of inpatient stays | No. of outpatients visits | No. of inpatient stays | No. of outpatients visits | Total |
| Seafood toxins | Toxic effect of ciguatera fish poisoning (T61.0) | 2 ± 1.4 | 8 ± 3 | 2 (0–3) | 4 (2–7) | 6 (3–9) |
| | Toxic effect of scombroid (histamine-like) fish poisoning (T61.1) | 2 ± 0.8 | 4 ± 1.1 | 1 (1–3) | 2 (1–3) | 3 (2–5) |
| | Toxic effect of other fish and shellfish poisoning (T61.2) | 260 ± 22 | 318 ± 64 | 193 (166–219) | 163 (109–218) | 356 (295–416) |
| | Toxic effect of other seafood (T61.8) | 45 ± 17 | 115 ± 24 | 33 (13–54) | 59 (39–79) | 92 (64–122) |
| | Toxic effect of unspecified seafood (T61.9) | 29 ± 12 | 99 ± 22 | 21 (8–35) | 51 (32–69) | 72 (49–96) |
| | Subtotal | 336 ± 44 | 543 ± 99 | 251 (215–287) | 279 (218–340) | 530 (458–600) |
| Plant toxins | Toxic effect of ingested mushrooms (T62.0) | 152 ± 92 | 312 ± 240 | 120 (24–227) | 183 (28–369) | 303 (118–515) |
| | Toxic effect of ingested berries (T62.1) | 1 ± 0.0 | 4 ± 0.6 | 1 (1–1) | 2 (1–2) | 3 (2–3) |
| | Toxic effect of other ingested (parts of) plant(s) (T62.2) | 167 ± 30 | 241 ± 33 | 124 (87–161) | 124 (96–152) | 248 (201–294) |
| | Subtotal | 319 ± 104 | 556 ± 253 | 244 (143–357) | 309 (153–497) | 554 (362–770) |
| Mycotoxins | Toxic effect of aflatoxin and other mycotoxin food contaminant (T64) | 1 ± 0.8 | 7 ± 4 | 1 (0–2) | 4 (1–6) | 5 (1–8) |
| Total | | 656 ± 123 | 1,106 ± 276 | 496 (388–614) | 592 (423–790) | 1088 (883–1315) |

HIRA, Health Insurance Review and Assessment Service; ICD, International Classification of Diseases; No., number.