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Characteristics and Trends with Respect to Unintentional Pesticide Poisoning Mortality and Hospitalization in Taiwan, 1999-2008

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1. Introduction

Pesticides are a group of chemicals widely used in agriculture to control insects, microorganisms, fungi, weeds, and other pests. Control of these pests serves to increase crop yield and decrease manual labour.

In 2000 and 2001, over 5 billion kilograms of pesticides were used annually throughout the world [1, 2]. Between 1999 and 2008, 9.6 million kilograms of pesticides were used annually in Taiwan. This was responsible for 0.8% of the total pesticide use in the world [2]. Efforts should be made to assess the risks of pesticides in the general population in terms of the extent and types of exposure.

A number of approaches have been taken by researchers to acquire information on pesticide poisoning in Taiwan. Pesticide exposure in Taiwan was recently evaluated using the nationwide registry maintained by the Network of Taiwan's Poison Control Centers (PCC) [3]. Over the course of eight years (1985-1993), 23,436 telephone calls concerning human poisoning exposure were recorded. The most frequent cause for poisoning exposure was pesticides (29.3%). Another study reported that there were 4,799 organophosphate pesticide (OP) exposures from July 1985 through December 2006 during a 21.5 year [4]. These studies were based on information collected in telephone interviews on poisoning exposures. The source population was poorly specified and therefore these figures could not be used for estimating rates of poisoning.

We used the nationwide population-based registry to assess the occurrence of pesticide poisoning episode in Taiwan between 1999 and 2008. To our knowledge, this is the largest and most complete nationwide population-based study to examine the characteristics and trends of unintentional pesticide poisoning mortality and hospitalization in Taiwan by sex, age, and cause between 1999 and 2008.

2. Materials and methods

2.1 Database

Data were collected from the official Vital Statistics System for the period 1999 to 2008. This system collects data from all administrative divisions in Taiwan.

According to law, each division officer must report death certificate to the Health Department of the Executive Yuan. Death certificate includes demographic factors, date and site of death, and cause of death (according to the International Classification of Diseases, 9th Revision, Clinical Modifications). The coding of injury death did not change from 1999 to 2008. Injuries were classified by intent and mechanism. Unintentional injuries included MVI (E810-E825), poisoning (E850-E869), falls (E880-E888), fire and flames (E890-E899), drowning (E910), suffocation (E911-E913), and other. Mortality rates were age-adjusted to each year's standard population. Annual population estimates were taken from the Statistical Yearbook of the Ministry of Interior. The data was then age-adjusted to the Year 2000 Standard Population of World Health Organization (WHO).

In this study, we used the Health Insurance Database from 1999 to 2008 released by the Taiwan National Health Research Institute (NHRI) in 2009 to investigate the trend of hospitalization due to pesticide poisoning.

Taiwan inaugurated its National Health Insurance (NHI) program in 1995 to finance healthcare for all citizens of Taiwan. There are currently 23.03 million enrollees covered by the program, representing over 99% of the island's population. The National Health Insurance Research Database 2009 (NHIRD) contains all the medical claims data as well as a registry of the 23.03 million enrollees covered by the NHI. The NHIRD, nationwide population-based dataset, provides an excellent opportunity to examine the trend of hospitalization due to unintentional pesticide poisoning.

This study was exempt from full review by the Institutional Review Board, as the dataset used consisted of de-identified secondary data released to the public for research purposes.

2.2 Statistical analysis

We calculated mortality and hospitalization rate using the number of poisoning as the numerator and the denominator was based on the mid-year population in the "population by age report" provided by the Ministry of the Interior. Data were age-adjusted by the direct method to the 2000 world standard population from the WHO. Afterwards, we calculated ten-year trends in unintentional poisoning mortality and hospitalization rates and categorized them by gender, age, and type of pesticide.

Six age groups on the Department of Health's classification were used: infants and toddlers aged 0-4, child aged 5-14, young adults aged 15-24, mature adults aged 25-44, middle-aged adults aged 45-64, and elderly aged 65 or more. With regards to NHI hospitalization data, since Medical facilities are required to file NHI claims on a monthly basis and the same episode may be reported several times if the hospitalization extends over different months. This was taken into account by accepting a hospitalization with a given ID and hospitalization date only once. All the data were analyzed by SPSS 18.0 software. Simple linear regression was used to test the trends of injury mortality rates. The dependent variable in the regression equation was the mortality rate or hospitalization rate, and the independent variable was the year.

3. Result

3.1 Mortality rate and trends

During the 10-year period from 1999 to 2008, unintentional pesticide poisoning accounted for 594 deaths in Taiwan, representing a mortality rate of 0.2405 per 100,000 person-years (Table 1). Males, the dominant group, accounted for 77% (457/594) of pesticide poisoning deaths (Table 1). Men demonstrated a mortality rate 3.4 times higher than women (0.3708 versus 0.1097 per 100,000 person-years). Decreasing trends in unintentional pesticide poisoning death rates after 1999 were seen for both genders (Figure 1).

		Age groups		0-4		5-14		15-24		25-44		45-64		65+		Overall	
		No.	Rate	No.	Rate	No.	Rate	No.	Rate	No.	Rate	No.	Rate	No.	Rate	No.	Rate
Mortality rate	Total	1	0.0075	0	0	27	0.0750	164	0.2169	206	0.4431	196	0.9324	594	0.2405		
	Male	1	0.0144	0	0	24	0.1291	134	0.3499	170	0.7417	128	1.2113	457	0.3708		
	Female	0	0	0	0	3	0.0176	30	0.0804	036	0.1516	68	0.6510	137	0.1097		
		No.	Rate	No.	Rate	No.	Rate	No.	Rate	No.	Rate	No.	Rate	No.	Rate	No.	Rate
Hospitalization rate	Total	200	1.3394	53	0.1701	241	0.6801	1588	2.0840	2527	5.4376	1709	8.2515	6328	2.6193		
	Male	131	1.6294	33	0.2029	188	0.9943	1186	3.0792	1878	8.2369	1249	12.0132	4666	3.8545		
	Female	69	1.0228	20	0.1345	63	0.3475	402	1.0624	648	2.7095	460	4.4500	1662	1.3813		

Table 1. Numbers of deaths and age and sex standardized mortality rates (per 100,000 person-years) from unintentional pesticide poisoning, Taiwan, 1999-2008

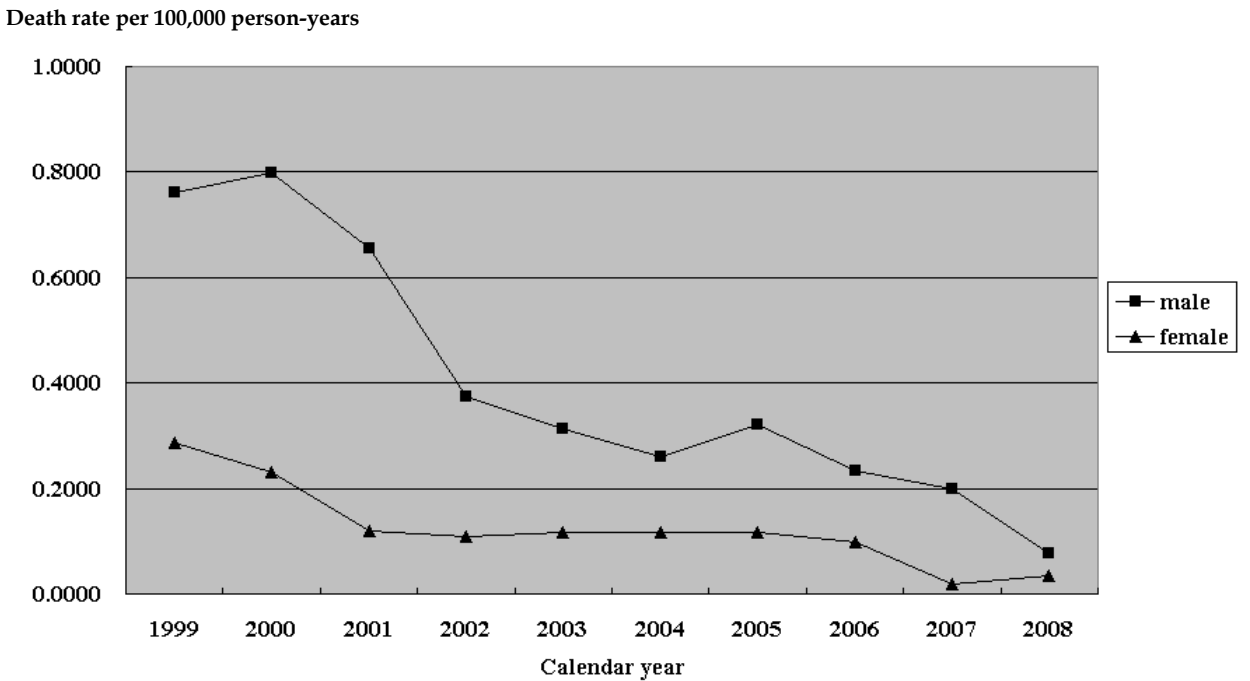


Fig. 1. Unintentional pesticide poisoning mortality rate (per 100,000 person-years) by gender, Taiwan, 1999-2008.

With regards to age, adult aging from 45 to 64 (0.44/100,000 PY or 10^{-5} PY) and elderly aging above 65 (0.93×10^{-5} PY) consistently had higher mortality rates than other age groups. The

unintentional pesticide poisoning mortality rate declined, mainly because of a decrease in the mortality rate of adults aging 45 to 64 and elderly aging 65 and above. The population aged 65 or more and 45-64 demonstrated a declining trend in mortality, with a drop of 90.1% and 87.8%, respectively ($p<0.001$) (Figure 2).

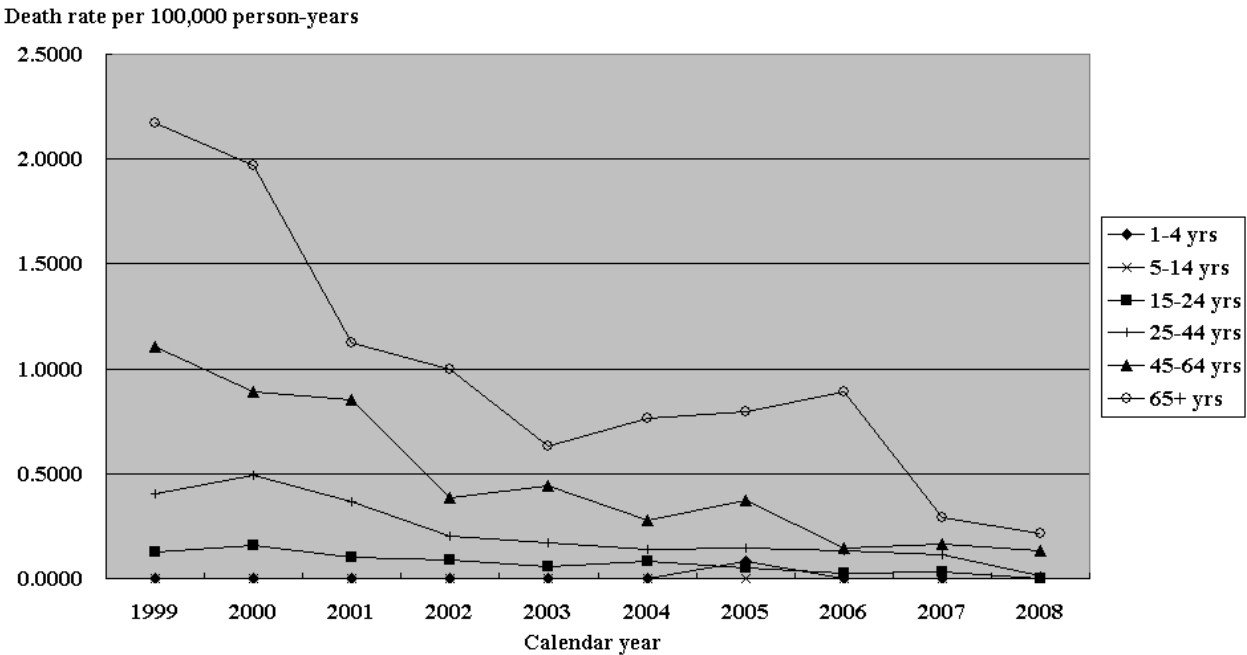


Fig. 2. Unintentional pesticide poisoning mortality rate (per 100,000 person-years) by age group, Taiwan 1999-2008.

3.2 Hospitalizations and trends

Between 1999 and 2008, there were 6,328 hospitalizations in Taiwan caused by unintentional pesticide poisoning, representing a hospitalization rate of 2.6193 per 100,000 person-years (Table 1). The hospitalization rate decreased by about 60%; this change was statistically significant ($p<0.001$).

The results showed that males were at higher risk of hospitalization as well (3.8545 per 100,000 person-years versus 1.3813 per 100,000 person-years). Decreasing trends in hospitalization rate due to unintentional pesticides poisoning after 1999 were seen in both genders (Figure 3). In terms of age, elderly aging above 65 had the highest hospitalization rate (8.2515 per 100,000 person-years).

3.3 Pesticides responsible for hospitalization

The Vital Statistics System applies a three-digit E863 code for unintentional poisoning by agriculture and horticultural chemical and pharmaceutical preparations, which restricts further analysis of different types of pesticides associated with unintentional poisoning deaths. However we were able to retrieve information on pesticide types most often responsible for poisoning from the hospitalization data.

Table 2 presents the hospitalization for major types of pesticide poisoning including “Organophosphate insecticides” (hospitalization rate: 1.2247 per 100,000 person-years), “unspecified insecticides” (hospitalization rate: 0.5152 per 100,000 person-years), “herbicides” (hospitalization rate: 0.4495 per 100,000 person-years) and “unspecified agricultural and horticultural chemical and pharmaceutical preparations other than plant

foods and fertilizers” (hospitalization rate: 0.2117 per 100,000 person-years). The unintentional pesticide poisoning hospitalization rate declined significant over time (trend test $p<0.001$), mainly because of a decrease in organophosphate insecticides and herbicide hospitalization for the adult and elderly hospitalization rate. (Figure 4 and Figure 5)

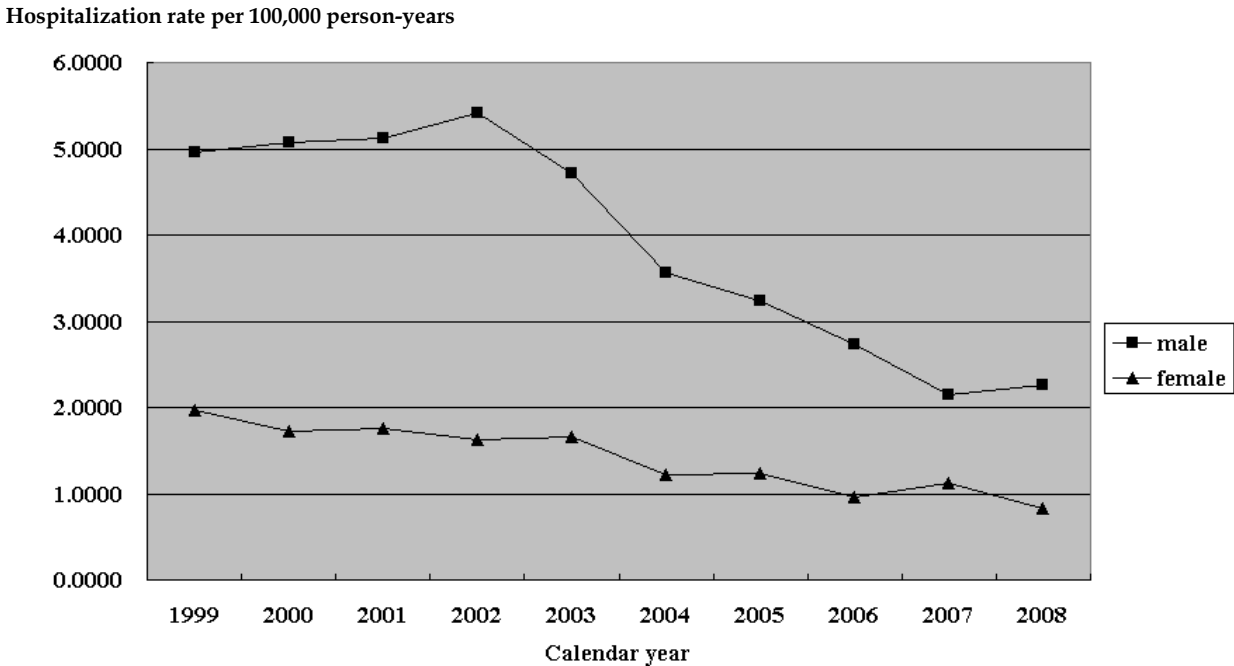


Fig. 3. Unintentional pesticide poisoning hospitalization rate (per 100,000 person-years) by gender, Taiwan, 1999-2008.

3.4 Occupations of the unintentional pesticide poisoning deaths and hospitalizations
The Vital Statistics System categorizes farm workers, forest workers, fishermen, and ranch workers into one occupational group. This group accounted for 98 deaths (16.5%). The 151 affected handicap, long-term sick, or old fragile health group (25.4%) represented a large proportion of unintentional pesticide poisoning deaths. Most of the 6328 episodes of unintentional pesticide poisoning hospitalization were among farm workers (N=3007, 47.5%) (data not shown).

4. Discussions

The results from our nation-wide analysis indicate that both mortality and hospitalization rate due to unintentional pesticide poisoning was decreasing after 1999 both in men and women. The results also show that men were at higher risk of mortality and hospitalization. The mortality and hospitalization rates were the highest among elderly above 65 years of age. “Organophosphate insecticides”, “unspecified insecticides”, “herbicides” and “unspecified agricultural and horticultural chemical and pharmaceutical preparations other than plant foods and fertilizer” were the major types of pesticide poisoning.

4.1 Unintentional pesticide poisoning mortality and hospitalization by gender
Calvert et al. [5] identified acute pesticide poisoning cases in agricultural workers from 1998 to 2005 from the Sentinel Event Notification System for Occupational Risks-Pesticides (SENSOR-Pesticides) program in the US. The authors found that acute pesticide poisoning

Category	Hospitalization			Hospitalization rate per 100,000 person years		
	Total (%)	Male (%)	Female (%)	Total	Male	Female
Accidental poisoning by insecticides of organochlorine compounds (E863.0)	27 (0.43)	22 (0.47)	5 (0.30)	0.0116	0.0192	0.0039
Accidental poisoning by insecticides of organophosphorus compounds (E863.1)	2975 (47.01)	2263 (48.50)	712 (42.84)	1.2247	1.8640	0.5858
Accidental poisoning by carbamates (E863.2)	170 (2.69)	135 (2.89)	35 (2.11)	0.0715	0.1143	0.0282
Accidental poisoning by mixtures of insecticides (E863.3)	97 (1.53)	70 (1.50)	27 (1.62)	0.0410	0.0597	0.0221
Accidental poisoning by other and unspecified insecticides (E863.4)	1197 (18.92)	842 (18.05)	355 (21.36)	0.5152	0.7230	0.3059
Accidental poisoning by herbicides (E863.5)	1103 (17.43)	830 (17.79)	273 (16.43)	0.4495	0.6763	0.2205
Accidental poisoning by fungicides (E863.6)	9 (0.14)	7 (0.15)	2 (0.12)	0.0040	0.0061	0.0016
Accidental poisoning by rodenticides (E863.7)	238 (3.76)	130 (2.79)	108 (6.50)	0.1054	0.1126	0.0983
Accidental poisoning by fumigants (E863.8)	4 (0.06)	2 (0.04)	2 (0.12)	0.0016	0.0015	0.0017
Accidental poisoning by other and unspecified agricultural and horticultural chemical and pharmaceutical preparations other than plant foods and fertilizers (E863.9)	508 (8.03)	365 (7.82)	143 (8.60)	0.2117	0.3034	0.1197
Overall	6328 (100.00)	4666 (100.00)	1662 (100.00)	2.6193	3.8545	1.3813

Table 2. Annual hospitalizations and hospitalization rate per 100,000 person-years due to unintentional pesticide poisoning

rate was almost two fold higher in female agriculture workers compared to males. In a hospital-based study at emergency departments (ED) in two medical centres in southwest Taiwan, 1512 poisoning cases were enrolled [6]. The authors estimated 4.2 poisonings per 1000 ED visits between January 2001 and December 2002. The female to male ratio of poisoning-related emergency department visits was 1.2. Overall, 66.1% of the poisoning exposures involved suicidal intent. Pesticide poisoning accounted for 14.5%. Based upon the above data, it was estimated that unintentional pesticide poisoning accounted for 0.21 cases of poisoning per 1000 ED visits. Our study showed that mortality as well as hospitalization rates were 3.4 and 2.8 times higher in male than female, respectively. Possible explanations for the differences in risk of unintentional pesticide poisoning in gender are the risk of exposure, rate of ascertainment or susceptibility.

4.2 Unintentional pesticide poisoning mortality and hospitalization by age

Lee et al. [6] reported that age greater or equal to 61 years was a significant predictor for poisoning-related fatalities (OR 4.3, 95% CI 2.6-7.2). The unintentional pesticide poisoning mortality rate increased with age, presumably due to the combination of low education and economic levels and higher fatality in the elderly [7].

4.3 Insecticide information on the pesticides responsible for pesticide poisoning

Calvert et al. [5] showed that insecticides alone or in combination with other pesticides were implicated in more than half of the pesticide poisoning cases (N=1,761, 54%). Cholinesterase inhibitors (organophosphates and N-methyl carbamates) were prominent among the insecticides (N=892, 51%), particularly chlorpyrifos (N=190), methamidophos (N=130), dimethoate (N=84), malathion (N=78), and diazinon (N=70).

In the report of Lin et al. that the top five compounds in the organophosphate poisoning, based on the Network of Taiwan's Poison Control Centers (PCC), were from mevinphos (18.4%), chlorpyrifos (17.6%), methamidophos (8%), dimethoate (5.2%), and fenitrothion (4.9%) [4], whereas the most fatal compounds were mevinphos (138 deaths/524 poisoning), methamidophos (68/524), dimethoate (33/524), chlorpyrifos (30/524), and parathion (25/524). With the development of agriculture, more and more victims were exposed to new types of insecticides and herbicides, such as mevinphos, methamidophos, dimethoate, chlorpyrifos, parathion, and paraquat. Paraquat is one of the most commonly used herbicides in Taiwan and has been the most common lethal agent of poisoning for a long time. Some measures have to be taken by authorities, including banning some of the most toxic pesticides such as WHO Pesticide Hazard Class I organophosphates and dimethyl organophosphates, and promoting less use of pesticides.

4.4 Occupations of the affected unintentional pesticide poisoning

Pesticide poisoning is a typical occupational disease among agricultural workers. Our study found agricultural workers were at greater risk of pesticide poisoning hospitalization than non-agricultural workers. A variety of work-related factors are related to unintentional pesticide poisoning such as pesticide usage, pesticide application days, hazardous practices, and poor hygiene[8].

4.5 Factors that contributed to unintentional pesticide poisoning

The most common job category related to pesticide exposure was pesticide handlers 33% (N=1,068), and they were performing routine work without pesticide application 67% (N=2,135). The most common factors contributing to pesticide exposure were off-target drift, early reentry into a recently treated area, and use in conflict with the label [5].

4.6 Injury pyramid of unintentional pesticide poisoning

An injury pyramid is often used graphically to depict the relative effect of fatal and nonfatal injuries from top to bottom [9]. The variant pyramid size and shape represents the magnitude and nature of the injury cause. Analyzing the size and shape of each injury pyramid is useful in the assessment of the relative frequency and lethality of the injury mechanism and intent. In our study, unintentional pesticide poisonings was responsible for 594 deaths and 6,328 hospitalizations in Taiwan during the 10-year period from 1999 to 2008. The type of injury pyramid can be categorized as the classically shaped pyramid because of the low case-fatality ratio. Previous studies showed that the poisoning-related fatality rate was in the range of 4.3% to 5.7% in Taiwan based on hospital-based data [6].

5. Limitations

Several limitations need to be considered in the interpretation of our findings. First, hospitalization data has over-presentation of severe poisoning and symptoms, because of both self-selection to the hospital polyclinics and admission to the hospital care. The quality

of diagnostic practice and criteria for hospitalization may vary and there is a possibility of under-reporting of pesticide poisoning in Taiwan.

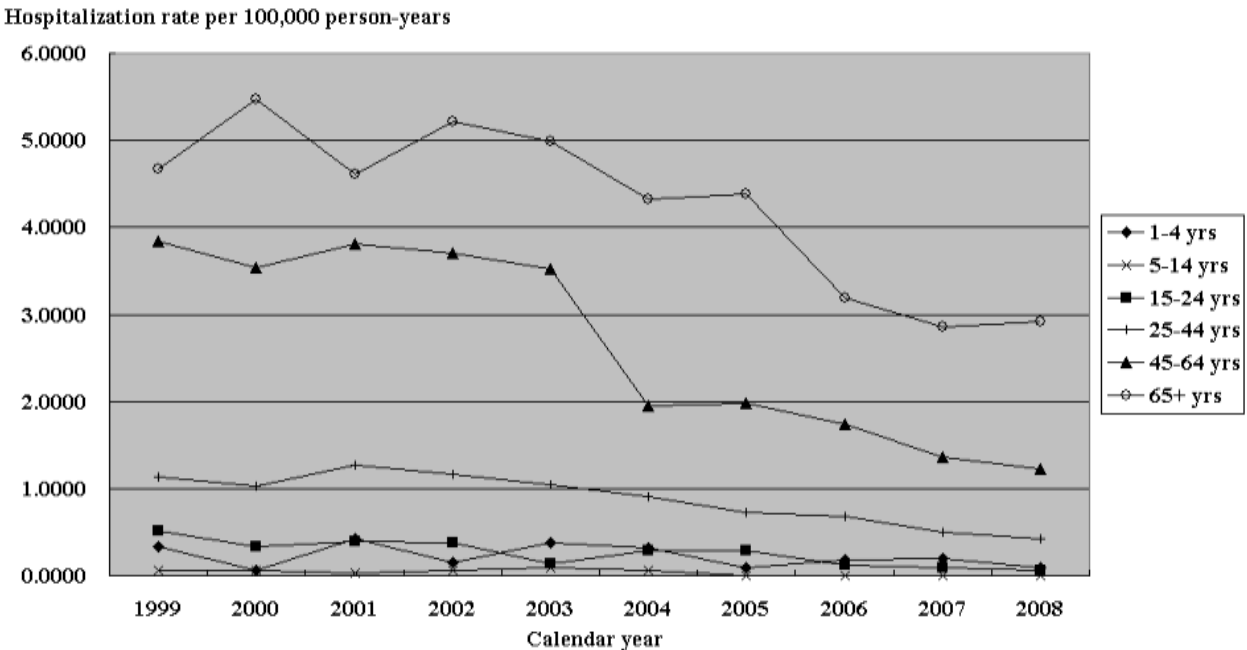


Fig. 4. Unintentional organophosphate insecticides poisoning hospitalization rate (per 100,000 person-years) by age group, Taiwan, 1999-2008.

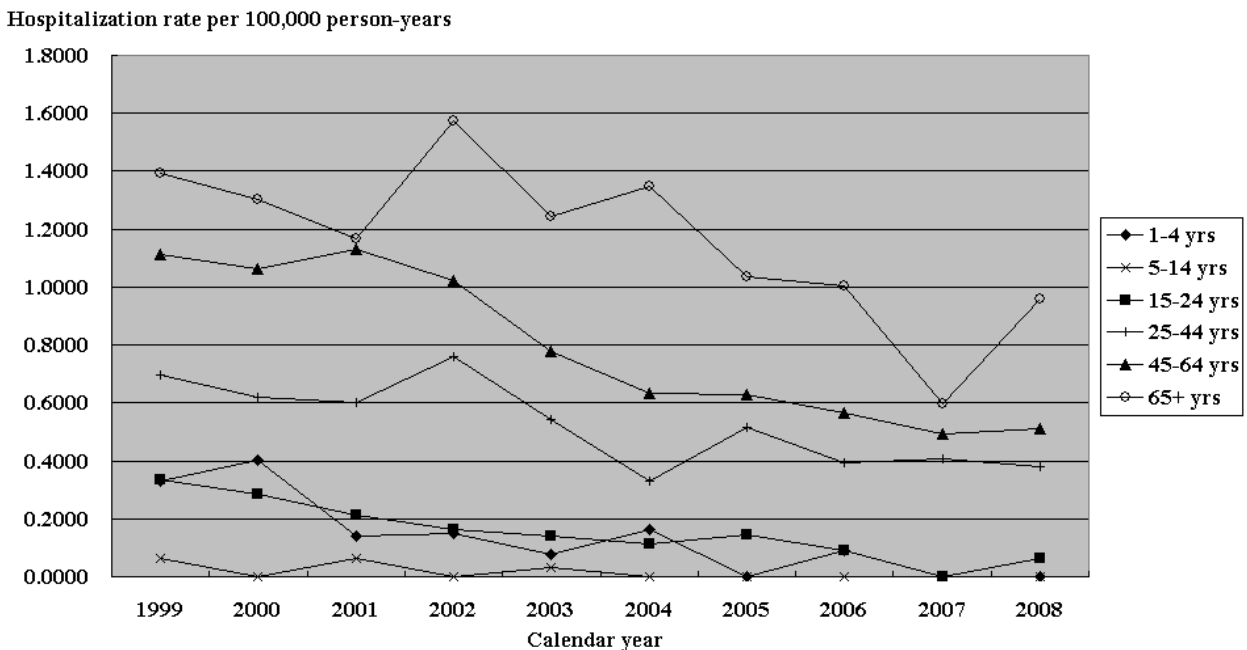


Fig. 5. Unintentional herbicide poisoning hospitalization rate (per 100,000 person-years) by age group, Taiwan, 1999-2008.

Second, the comorbidity diagnoses, which rely totally on claims data reported by physicians or hospitals, may be less accurate than if all individuals were assessed through a single standardized procedure [10]. Health professionals may not receive much training in environmental toxicology or pesticide poisoning. The signs and symptoms of pesticide

poisoning often resemble those of more common conditions, which may be diagnosed preferentially. The NHIRD used discharge diagnoses provided by treating physicians; no standardized criteria are used to define hospitalization cases. This increases the probability for case misclassification. The NHIRD, designed as an administrative dataset, does not include some important individual characteristics for further analyses such as smoking, alcohol consumption, all of which may contribute to death or hospitalization. The mortality and hospitalization rates may be underestimations, because of possible under-reporting of cases to the databases in the analyses. Administrative databases are known to be subject to possible undercoding and overcoding errors[11]. The difficulty of receiving reimbursement through workers' compensation may also bias health care providers diagnosis and reporting of episodes of unintentional pesticide poisoning. The health care professionals may fear that their patients may be subject to retaliation.

6. Strengths of this study

Litchfield [12] categorized studies on acute pesticide poisoning in agriculture into three categories: clinical case reports, descriptive epidemiology studies, and cross-sectional studies. Several studies conducted in China, India, and Taiwan was based on hospital-based case reports [3, 4, 6, 13, 14]. They were insufficient of information on the source population for estimation of poisoning rates. A particular strength of this study is the use of two nationwide population-based data sets, allowing us to trace medical services received by all patients after poisoning. Using the same ICD-9-CM codes over the study period would retain the internal validity of the temporal trend analyses. To our knowledge the present study is the most complete nationwide population-based study conducted to assess the risk of pesticide poisoning and evaluate time trends for pesticide poisoning.

7. Conclusion

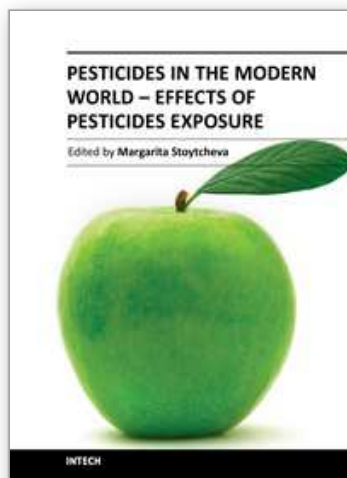
Men were higher risk of mortality and hospitalization rates from unintentional pesticide poisoning. Although the mortality and hospitalization rates from unintentional pesticide poisoning have declined, development of prevention programs to reduce the "organophosphate insecticides", "unspecified insecticides", "herbicides" and "unspecified agricultural and horticultural chemical and pharmaceutical preparations other than plant foods and fertilizers" poisoning rates remain important in the future. There is relatively little known about the health effects of chronic pesticide exposure [15, 16]. Surveillance of pesticide poisoning is important for development of effective policies, practices and regulations for prevention of hazardous pesticide exposures and poisoning. Currently no authority in Taiwan is in charge of pesticide poison surveillance.

8. Acknowledgements

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Pesticides in the Modern World - Effects of Pesticides Exposure

Edited by Dr. Margarita Stoytcheva

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The introduction of the synthetic organochlorine, organophosphate, carbamate and pyrethroid pesticides by 1950s marked the beginning of the modern pesticides era and a new stage in the agriculture development. Evolved from the chemicals designed originally as warfare agents, the synthetic pesticides demonstrated a high effectiveness in preventing, destroying or controlling any pest. Therefore, their application in the agriculture practices made it possible enhancing crops and livestock's yields and obtaining higher-quality products, to satisfy the food demand of the continuously rising world's population. Nevertheless, the increase of the pesticide use estimated to 2.5 million tons annually worldwide since 1950., created a number of public and environment concerns. This book, organized in two sections, addresses the various aspects of the pesticides exposure and the related health effects. It offers a large amount of practical information to the professionals interested in pesticides issues.

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