International Journal of Health, 4 (x) (2016) 151-154

International Journal of Health

Website: www.sciencepubco.com/index.php/IJH
doi: 10.14419/ijh.v4i2.6684
Research paper

Trends of fire deaths and effects of fire safety measures in Taiwan during 1971-2015

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Abstract

Purpose: Although fire causes 2 % of deaths of the global accidents in Taiwan, injury or death caused by fire is frequent and largely preventable.
Approach: Using the Health and Vital Statistics, Fire Losses and Casualties Table, Abridged Life Tables, and Services for Fire Fighting by official publications during 1971-2015, we approached the trends of population, ages, gender, and social costs associated with fatal fire and evaluated the effects of fire safety measures.
Results: The higher mortality rate of fire death was in the elders. Fire death rates were 1.92 folds higher risk in males than in females ($p < 0.05$). The potential years of life lost (PYLL) implied the most efficient evaluation for the fire safety measures. Fire mortality and casualty could be prevented by fire prevention, fire rescue and emergency medical measures effectively. The most significant effect of fire safety measures was evasion training that adopted the indicator of mortality per 102 burned houses (MBH).
Conclusions: Therefore, fire prevention efforts should concentrate on males, and elders. The decreasing of fire numbers should be developed and encouraged.

Keywords: *Fire; Potential Years of Life Lost; Evasion Training.*

1. Introduction

On average, there were 220 people died, 442 people injured, and 148 burned houses per year in Taiwan from 1971 to 2015 (Ministry of Health and welfare, 1971-2015b). Although fire caused 2 % of deaths of the global accidents, fire made health, social, and environmental damage immensely. Therefore, the National Fire Agency set up in 1995, which adopted in fire prevention, rescue, and emergency medical services, and expanded organizations to cope with the disasters in 2001(National Fir Agency, Ministry of Interior, 2015).
Injury or death caused by fire is frequent and largely preventable (Barillo & Goode 1996). The growing emphasis on fiscal responsibility, annual estimates of injury costs can be as meaningful and relevant to safety and health measures as data on injury incidence and severity (Etter,1987). This study attempts to define the trends of population, ages, gender, locations, and social costs associated with fatal fire, and furthermore determine the changing of fire deaths after the intensification of fire mitigation during 1971-2015. The results would help to assess the future needs of support services for the fire fighting and public health units to meet the demands of fire safety.

2. Methods

Using Health and Vital Statistics, Fire Losses and Casualties Table, Abridged Life Tables, and Services for Fire Fighting by official publications during 1971-2015, (Ministry of Health and Welfare, 1971-2015b; Ministry of Interior, 2015), we computed the life expectancy due to elimination of death caused by fire and flames (ICD-9, E890-E899; ICD-10, X00-X09). The results were computed for the race- gender specific population in Taiwan.
There are three ways of weighting the number of deaths due to fire cause in the study. The form for the crude death rates (CDR) is CDR = $\sum_{i=0}^{\infty} di \; / \; \sum_{i=0}^{\infty} ni$, where di is the number of deaths from the cause under concern in the ith age group, and ni is the number of persons under concern in the ith age group (Miettinen 1972). The form for potential years of life lost (PYLL) is PYLL =Σ(70–age at the time of death). The form for average years of life lost (AYLL) is AYLL= PYLL / number of death.
Three indicators are adopted for explaining the safety measures, such as proportion of smoking cause (PSC), mortality per 10^2 burned houses (MBH), and fire casualty rate (FCR). PSC and MBH are the indicators of fire prevention effects; PSC is meant to fire safety education, and MBH is meant to evasion training.FCR is as the indicator of fire rescue and as the indicator of emergency medical services effects.
In order to confirm the efforts of fire safety measures, another four of fire services and call frequency initiatives are adopted for the analysis of impacts on mortality and casualty during 1995-2015. Rates of unqualified recheck (RUR) was as the initiatives of fire prevention. Persons attendance at every fire accident (PAF), engines attendance at every fire accident (EAF), and number of saving per fire (SAV), are as the rescue, and emergency medical services.
Differences between various groups were evaluated using Student's t-test and x^2 -test. The level of significance was set at 0.05.

3. Results

3.1. Incidence

During 1971-2015 the total number of fires, and burned houses, and casualty were increased from 2649, 1943, and 344 to 1704, 1477, and 365. The number of fires (28254), and burned houses (3384) were both peak in 1999 and declined to the lowest after 2000. The number of casualty (1195) was peak in 1993 and declined to the lowest after 1995.

3.2. Mortality

The mortalities during 1971-2015 by nine year interval are seen in table 1. The average CDR is 1.10 per 10^5 persons. Males appear to be about 2 folds greater risk than females for those during 15 - 64 years age group, and over 64 years age group. The average CDRs of males, females, and both sexes are 3.95, 2.03, and 3.01 per 10^5 persons over 64 years age group, which are about 3.76 folds, 2.11 folds, and 2.98 folds greater risk than the average CDRs of males, females, and both sexes under15 years age group (all $p<0.05$). Likely they are about 3.21 folds, 2.94folds, and 3.24 folds greater risk than the average CDRs of males, females, and both sexes in 15-64 years age group in male, female, and both sexes (all $p<0.05$). The average CDRs of males, females, and both sexes are 2.29, 1.85, and 1.85 per 10^5 persons during 1989-1997 which declined to 0.61, 0.33, and 0.46 per 10^5 persons during 2007-2015 (26.64 %, 17.83%, and 24.86 %; $p < 0.05$). The average CDRs of males, females, and both sexes are 1.70, 1.44, and 1.58 per 10^5 persons under 15 years age group during 1989-1997 which declined to 0.33, 0.27, and 0.30 per 10^5 persons during 2007-2015 (19.41 %, 18.75 %, and 18.99 %; $p < 0.05$). The average CDRs of males, females, and both sexes are 2.21, 1.46, and 1.72 per 10^5 persons in 15-64 years age group during 1989-1997 which declined to 0.47, 0.25, and 0.34 per 10^5 persons during 2007-2015 (21.27 %, 17.12 %, and 19.77%; $p < 0.05$). The average CDRs of males, females, and both sexes are 5.12, 2.85, and 4.08 per 10^5 persons over 65 years age group during 1989-1997 which declined to 1.92, 0.88, and 1.41 per 10^5 persons during 2007-2015 (37.50%, 30.88%, and 34.56 %; $p < 0.05$). The declined rates were larger in females than in males. The declined rates were smaller in over 64 years age group than in under 15 years age group, and in 15 – 64 years age group respectively.

3.3. Potential years of life lost (PYLL), and average years of life lost (AYLL)

Social costs caused by fire death are displayed in table 2. Comparing these totals by sex, we see that there are greater losses in potential life years among men than women with fire deaths. All of them were with an average loss of 42 years by affected individuals. The PYLL of males, females, and both sexes were 10216, 7103, and 17455 person years during 1989-1997, which declined to 2038, 586, and 2623 person years during 2007-2015 (19.95 %, 8.25 %, and 15.03%; $p < 0.05$). The AYLL of male, female, and both sexes were 41, 51, and 45 person years during 1989-1997, which declined to 29, 28, and 29 person years during 2007-2015 (70.73 %, 54.90 %, and 64.44 %; $p < 0.05$).

Table 1: Ages and Sex Distribution of Fire Mortality per 10^5 Persons (1971-2015)

	<15years			15-64years			>64years			Total		
Year	Male	Female	Both	Male	Female	Both	Male	Female	Both	Male	Female	Both
1971-1979	1.04	0.88	0.96	0.99	0.44	0.69	3.93	3.17	3.01	1.10	0.66	0.88
1980-1988	1.37	1.41	1.39	1.63	0.85	1.22	6.02	2.78	4.44	1.76	1.43	1.43
1989-1997	1.70	1.44	1.58	2.21	1.46	1.72	5.12	2.85	4.08	2.29	1.85	1.85
1998-2006	0.80	0.81	0.81	0.87	0.51	0.66	2.75	1.46	2.11	1.03	0.65	0.90
2007-2015	0.33	0.27	0.30	0.47	0.25	0.34	1.92	0.88	1.41	0.61	0.33	0.46
Total	0.33	0.27	0.30	0.47	0.25	0.34	1.92	0.88	1.41	0.61	0.33	0.46

Table 2: Estimated Number of Lost Life Years Associated with the Incidence of Fire, Taiwan, 1971-2015

	PYLL (person years)			AYLL (years)		
Year	Male	Female	Both	Male	Female	Both
1971-1979	4367	2929	7169	47	59	50
1980-1988	7245	5415	12682	43	56	47
1989-1997	10216	7103	17455	41	51	45
1998-2006	4288	2258	6362	36	42	38
2007-2015	2038	586	2623	29	28	29
Total	5591	3618	9258	39	46	42

PYLL: potential years of life lost =Σ (70–age at the time of death). AYLL: average years of life lost = PYLL / number of death.

3.4. Effect s analysis for the safety measures

The proportion of smoking cause (PSC), mortality per 10^2 burned houses (MBH), and fire casualty rate (FCR) were 16.53%, 21.27, and 39.29 % during 1989-1997, which declined significantly to 8.98%, 8.79, and 25.44% during 2007-2015 (54.33%, 40.51%, and 64.75%; $p < 0.05$). The most significant effect of fire safety measures was evasion training that reflected the indicator of MBH (Table3).

Table 3: Estimated Major Cause of Fire Deaths and Casualty in the Buildings, Taiwan, 1971-20165

Year	PSC (%)	MBH (persons/ 10^2fires)	FCR (%)
1971-1979	11.63	7.02	34.05
1980-1988	11.75	11.61	44.84
1989-1997	16.53	21.70	39.29
1998-2006	12.40	8.52	23.01
2007-2015	8.98	8.79	25.44
Total	12.26	12.43	33.33

PSC: proportion of smoking cause. MBH: mortality per 10^2 burned houses. FCR: fire casualty rate.

3.5. Initiatives analysis

The rates of unqualified recheck (RUR) was 46.08 % during 1995-1997 that declined significantly to 9.46 % during 2007 – 2015,

(20.53%, $p < 0.05$). The persons attendance at every fire accident (PAF), engines attendance (EAF) at every fire incidence, and number of saving at every fire (SAV) were 21.19 , 5.68, and 0.15 during 1995 – 1997, which increased significantly to 215.74 persons / fire, 73.14 engines / fire, 0.32 person / fire during 2007 – 2015 (10.18 folds, 12.88 folds, 2.13 folds, $p < 0.05$) (Table 4).

Table 4: Fire Inspection, Services, and Call Frequency in Taiwan, 1995-2015

Year	RUR (%)	PAF	EAF	SAV
1995-1997	46.08	21.19	5.68	0.15
1998-2006	12.83	40.85	10.85	0.13
2007-2015	9.46	215.74	73.14	0.32
Total	16.14	122.66	40.08	0.22

RUR: rates of unqualified recheck. PAF: persons attendance at every fire accident.
EAF: engines attendance at every fire accident. SAV: number of saving at every fire.

The RUR was correlated with FCR ($r = 0.50$, $p < 0.05$). The PAF was correlated with SAV, and CDR respectively ($r = 073$, and -0.80, $p < 0.05$), The EAF was correlated with SAV, and CDR respectively ($r = 073$,and -0.80, all $p < 0.05$). These results indicated that the initiatives of fire rescue, and emergency medical services could save the life and decrease the fire death effectively (Table5).

4. Discussion

In the past 27 years (1974-2000), the crude death rate due to unintentional injuries overall dropped by 8.56%, however for fire it increased by 28.05% (Ministry of Health and Welfare, 1974-2000b). Therefore, the large number of losses and casualties due to fires in Taiwan continue to be a major challenge to the fire safety providers and society. Otherwise, there were downward trends of fires, burned houses, and number of casualty after 2000.The CDRs of under 15 years age group, in 15-64 years age group, and over 64 years age group were 1.58 per 10^5, 1.72 per 10^5, and 4.08 per 10^5 during 1989 - 1997 and declined to 0.30 per10^5, 0.34 per 10^5, and 1.41 per 10^5 during 2007 - 2015 (18.99 %, 19.77%, and 34.56 %; $p < 0.05$). These signs explained that fire death rates were fallen as a result of caring out the ROC Child Welfare Law of Children supervision and protection and the provision of the National Fire Agency (Children's Bureau Ministry of Interior, 2003; National Fire Agency Ministry of Interior, 2015).

Table 5: The Spearman's Rank Correlation Coefficient for Relationships between Fire Safety Initiatives with Respect to Life-Threatening Hazards from Fire, 1995-2015

parameter	SAV	CDR	MBH	FCR
RUR	0.00	0.38	0.28	0.50*
PAF	0.73*	-0.80*	-0.02	0.11
EAF	0.73	-0.80*	-0.00	0.15

*: the correlation coefficients were significant, $p < 0.05$

During 1971-1980, the average death rate (CDR=1.01 per 10^5 persons) in Taiwan was lower than the average CDR (4.60 per 10^5 persons; $p < 0.05$) in U.S.A.(Clark et al. 2000). During 1981-1900, the average death rate (CDR= 1.65 per 10^5 persons) in Taiwan was lower than in U.S.A (4.55 per 10^5 persons; $p < 0.05$), and in New Zealand (2.1 per 10^5 persons; $p < 0.05$)(Clark et al. 2000; Waller et al. 1998). During 1991-2000, the average death rate (CDR=1.61 per 10^5 persons) in Taiwan was similar to the average CDR (1.65 per 10^5 persons; $p > 0.05$) in U.S.A. but lower than the average CDR (4.60 per 10^5 persons; $p < 0.05$) in Iran (Clark et al.2000; Panjeshahin et al. 200). During 1996-2000, the average death rate (CDR= 1.25 per 10^5 persons) in Taiwan was similar to the average CDR (1.22 per 10^5 persons; $p > 0.05$) in Wisconsin U.S.A. (Stockhausen & Katcher 2001). For such incidences in Taiwan past 30 years were there in contrast to reports from developing countries, but conform to reports from developed countries.

Males appeared to be with a higher mortality than females for both adult age groups ($p < 0.05$). Most studies have also reported a preponderance of burnt males (Roger 1980, Bang & Mosbah 1988, Tejerina et al.1992, Reig et al. 1994, Elisdottir et al.1995, Barret et al. 1999). However, other studies have reported that female were the victims of fires more frequently than males in developing countries (Liu et al.1998, Mzezewa et al.1999). The declined rates were smaller in over 64 year age group than in under 15 years age group, and in 15 – 64 years age group respectively. It suggested that the elders are more vulnerable to fire fatality because they lack the capacity to take "mature independent escape action" (Marshall et al.1998, Mcgwin et al.1999). Our results agreed with these studies expectantly.

The PYLL, AYLL, and CDR of fire deaths were decreased about 85%, 36%, and 82 % [(17455-2623)*100/17455, (45-29)*100/45, and (1.85-0.33)*100/1.85] from during 1989-1997 to during 2007-2015. The value of the PYLL and AYLL were heavily influenced by age structure among different population, and were presented indexes that focuses more on the social, economic, and administration consequences of mortality rates (Hartunian et al.1980, Chuang et al.1993, Lai & Hardy 1999). The studies found that PYLL is the most efficient evaluation for the fire safety measures.

The PSC, MBH, and FCR of the fires were decreased about 46%, 59%, and 35% [(16.53-8.98)*100/16.53, (21.70-8.79)*100/21.70, and (39.29-25.04)*100/39.29] from during 1989-1997 to during 2007-2015. The three indicators are all effective for explaining the safety measures. The most significant effect of fire safety measures was evasion training that adopted the indicator of MBH. With comparing the changes of indicators between during 1971-1979 and 1989- 1997, and between during 1998-2006 and 2007-2015, we found that the change of indicators were more consistently in the later. A law of Children supervision and a provision of fire fighting both addressed the issue of how to decrease risks of deaths.

The fire safety efforts such as RUR, PAF, and EAF were confirmed to the effectiveness of fire safety measures that could decrease the death and .casualty in our studies, expectantly. During 1995-2013, the proportions of fir safety appropriations (about $ 20.78 millions dollars) are 8.74 % with fire prevention, 75.94 % with fire rescue and emergency medical services, and 15.32 % with fire investigations in 2002 (National Fire Agency Ministry of Interior, 2015). These signs implied that the process of the fire safety measures is parallel, the appropriation of fire prevention is light, but is effective. Therefore, if we weight the proportion of fire prevention appropriations, we will decrease the overall fire safety appropriations; as well as, if we emphasize the fire prevention initiatives, we would decrease the fire mortality and casualty.

5. Conclusion

The mortality rate was higher in male and in the elders. The PYLL implied the most efficient evaluation for the fire safety measures. Fire mortality and casualty could be prevented by fire prevention, fire rescue and emergency medical measures effectively. The most significant effect of fire safety measures was evasion training that adopted the indicator of MBH.

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