Reduction of post-shift traffic injuries among gasoline station workers: Are they related to the reduction of occupational gasoline vapor exposure?

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Abstract

Aims: Solvents exposure is known to impair psychomotor performances. With gasoline vapor recovery devices (GVRD) installed, this study should observe a decrease of traffic injuries after shift among gasoline workers.

Methods: The occupational injury registry data of 1991–2000 in a petrochemical company containing 20,000 workers were analyzed. Cumulative injury rate (CIR) was calculated to estimate lifetime risk. The potential workday loss (PWDL) and the potential salary loss (PSL), which summed up the expected workdays and salary loss assuming a uniform retirement age of 65, were calculated for traffic injuries. Workers of gasoline sales were compared with those without gasoline exposure for commuting traffic injuries. The rate ratio (RR) was calculated based on a person–time data.

Results: The CIR dropped 3.14 times during 1997–2000 for commuting accidents on the way back home compared with that during 1991–1992, and the PWDL and PSL dropped 25.2 and 21.5 times, respectively, which corresponded with the time of installments of GVRD. The RRs of commuting accidents on the way back home in the exposed group significantly decreased from 2.15 to 0.53.

Conclusions: The decrease of commuting injuries on journey back home for gasoline workers were probably related to the effective reduction of solvent exposure.

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Keywords: Cost of injury; Commute injury; Gasoline recovery device; Potential salary loss; Potential workday loss; Cumulative injury rate

1. Introduction

In the compensation law, the classification of the occupational injuries available while commuting to work and back to home has been under heavy debate for many decades (International Labour Office, 2002). Even under the promotion of the International Labor Office (ILO), no universal consensus on this issue was observed among different countries. This was probably the case due to other determinants of commuting accidents unrelated to work, including drugs or alcohol (Chipman, 1995; Sun et al., 1998; Salminen, 2000; Movig et al., 2004). In 1998, NIOSH expressed their concern that traffic-related motor vehicle crashes also occurred in

occupational mortalities. During the time period from 1980 to 1992, traffic-related motor vehicle crashes accounted for 20% of all fatal workplace injuries; however, events that occurred while traveling to or from work were not included (National Institute for Occupational Safety and Health, 1998). Most companies concentrated their efforts on the prevention of diseases and injuries occurring inside the factories, but the cost of traffic injuries from commuting was estimated from 2 to 6 times greater than those of workplace injuries (Miller, 1995). Since it is necessary for each employee to commute to and from the workplace by a means of transportation, it is worthwhile to explore whether commuting injury increases after a full day's exposure to solvents like gasoline vapor in the workplace.

From our limited knowledge, few studies have focused on the cause and compensation of commuting injuries resulting

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from exposure to solvents or other chemicals. These hazards could affect workers' psychomotor functions. Studies have found that psychomotor performances in adults could be impaired by occupational exposures to organic lead, benzene, toluene, *n*-hexane, and other solvents in gasoline (Morrow et al., 1990, 1992; Cairney et al., 2002). In Taiwan, lead was once present as tetraethyl lead in gasoline (Tenenbein, 1997), and was reduced to below 0.027 g Pb/L. The cord blood of newborns in Taiwan also showed a big reduction in lead concentrations (Hwang et al., 2004). Most volatile hydrocarbons in gasoline have a half-life of approximately more than 4–6 h, e.g., toluene was 7.5 h and benzene was 9–24 h in human body (Flanagan et al., 1990). The acute effects of petrol sniffing on psychomotor function usually occurred within 3–5 min and lasted for 5–6 h (Poklis and Burkett, 1977). After a full shift of inhaling gasoline vapors during one's working hours, the employee's psychomotor function could be severely affected. The persistence of such solvents and their metabolites could be related to the increased frequency and severity of traffic injuries on the journey back home.

To protect the worker's rights, a commuting accident has been regarded as a work-related injury regardless of the worker's occupational exposure in Taiwan since 1974. For example, the frequency of traffic injuries was about 63.1% of all occupational injuries from 1991 to 2000 in the studied petrochemical company in Taiwan. The registration number of automobiles increased from 10 to 17 million from 1991 to 2000, and the crash rates (number of accidents per 10,000 vehicles) from 1991 to 1999 were 4.6 to 1.5 (Statistical Yearbook of the Republic of China, 2004). The average incidence rate of traffic injury was 4.06 per 1000 workers of this petrochemical company, which was higher than 0.91 per 1000 workers of all industries in Taiwan from 1981 to 1987 (IOSH, 1996). Workers selling gasoline were exposed to gasoline vapors regularly in their normal working hours. Thus, the registry data of occupational injury could be used to determine if there was an increased incidence rate of traffic injury for workers exposed to gasoline, especially after a full day of work. This study also attempted to calculate the loss of human capital cost. Moreover, the study intended to determine if the cost of traffic injury declined as a result of the installation of gasoline vapor recovery devices, which presumably reduced the occupational gasoline exposure.

2. Materials and methods

From the 1991 to 2000 occupational injury registry data, the petrochemical company under study had approximately 20,000 employees. The company had a well-established Department of Industrial Safety & Environmental Protection, which regularly collected data of occupational injury and mortality with any man-hour loss, and reported disabling frequency and severity monthly since 1983. The reporting procedures were regularly followed by the Department of Industrial Safety & Environmental Protection, and were sim-

ilar to the recommendations of the Council of Labor Affairs (CLA), which were originally proposed by American National Standard Institute (ANSI). The report forms of occupational injury contained basic demographic data for every injury case and type of work, time and data of injury, time of worker's return-to-work, injured body parts (head, face, etc.), location of injury occurrence (further classified into inside the factory, outside the factory due to official business, on the way to work, and on the way back home), workdays loss, types of traffic tool, and kinds of disability (permanent disability, temporary disability, and death). In addition, it also contained a brief qualitative description on how the occupational injury occurred. According to the Labor Safety and Health Law in Taiwan, which was released in 1974, all commuting injuries were identified as occupationally related unless the workers obviously violated the traffic regulations during the injury, such as drunken driving, etc. There was also a stipulation in the regulations clarifying that occupational commuting injury after work only counted if the worker was on his/her regular route back home. For example, an injury could not be regarded as occupational if the worker bypassed another pub or shopping mall before returning home. Because the workmen's compensation of National Labor Insurance (NLI) only paid 70% of the insured wages for the sickness absence, the company usually paid the 30% of the remaining wages plus the uninsured part of wages in order to produce a financial incentive for the managers in preventing abuse or over-reporting. Therefore, the Occupational Safety and Health Committee of the oil company under study usually conducted a detailed investigation of each injury to prevent any abuse and the recurrence of the same type of injury. From all the 626 traffic injury cases, no case was under the influence of alcohol or drug. Thus, the quality of this registry data was accurate or at most under-reporting for minor injuries, which did not cost any loss of man-hours.

The salary data of employees, the total person-years of every division and location, and birth date of employees from the Department of Personnel in the administration division in this company were also collected. Employees' salary data included the information on worker's salary per month from 1991 to 2000. The potential salary loss of each injured worker could be calculated. The human capital cost of occupational injuries of this company was evaluated by the use of indices developed by Chang and Wang (1995), and Sheu et al. (2000), including the cumulative injury rate (CIR), the potential workday lost (PWDL), and the potential salary lost (PSL).

2.1. CIR

$$CIR_{20-64} = 1 - e^{-\sum (IR)_i \times \Delta t_i}$$

CIR_{20-64} is a cumulative injury rate with respect to the ages of 20–64 years in the study (or any specified age period). "I" represents age stratum (e.g., 20–29, 30–39, 40–49, 50–59, and 60–64 years old in our study). IR equals the injury

rate for a specific stratum, and Δt represents the number of years in each age stratum (e.g., if each age stratum is 10 years of age, then $\Delta t = 10$). The CIR can represent the lifetime risk of injury during the age period from 20 to 64 years.

2.2. PWDL, PSL

In the studied company, the total potential workdays lost were the sum of the potential workdays lost from the cases of fatality, potential workdays lost from the cases of permanent disability, and potential workdays lost from the cases of temporary dysfunction. Each worker was assumed to retire at the age of 65 years. The working capabilities were different between different kinds of dysfunction. Total potential salary lost was calculated with the same concept of total potential workdays lost. PSL is the total PWDL converted into a monetary value and adjusted for the incremental rate of labor productivity of an employee. It also discounted the future monetary value to the present value.

This company was divided into the following operational units including administration division, refinery division, gasoline sale division, petroleum exploring division, and research & development division, etc. Workers in the gasoline sale division had their offices near each service station, and were constantly exposed to gasoline vapors due to the fuel filling procedures outside their offices. The major division occupied about half of all the workers employed in this petrochemical company. Employees in the administration and research & development divisions worked generally in safer and more stable office buildings. Half of the workers in the petroleum exploring division worked also in the office environment, while others worked in the mine fields where exposure to volatile gasoline was low. The refinery division was comprised of three refinery plants. Because most of labor-intensive and/or hazardous tasks were contracted out, the regular employees in this division were also not exposed to high concentrations of organic solvents or gasoline as the data of regular air sampling showed. All other divisions without direct gasoline exposure (the gasoline-unexposed group) were combined, including administration, refinery, petroleum exploring, and research & development divisions. Simultaneously, workers in the gasoline sales division were enrolled as the gasoline-exposed group.

Three time periods according to the implementation of different types of gasoline vapor recovery devices (see below in Section 2.3) in the gasoline stations were divided by the 10 years from 1991 to 2000. The first period was from 1991 to 1992 in which no recovery devices for gasoline vapor were present. The second period was from 1993 to 1996 in which the balanced types of gasoline vapor recovery devices were set up in the gasoline service stations. Finally, the last period was from 1997 to 2000 during which the vacuum-assisted pump gasoline vapor recovery devices were installed. With the three periods of the 10 years, the association between

Fig. 1. Differences (marked by an asterisk) between the vapor balance recovery device (left) and the vacuum assist recovery device (right).

gasoline vapor exposure and post-shift traffic injury were evaluated.

The cumulative injury rate for traffic injuries occurring in different locations (on-job location, way to work, and way back home) was first calculated. Afterwards, the rate ratios with 95% confidence intervals based on person-time data and a large-sample method under the Poisson distribution were further computed based on the incidence rates of the gasoline-exposed versus gasoline-unexposed groups.

2.3. Vapor recovery devices

The two types of vapor recovery devices were “vapor balance” and “vacuum assist”. Fig. 1 shows their differences. The vapor balance type was equipped with a corrugated boot in the nozzle spout, which helped build up a “negative pressure” to pull gasoline vapors back into the underground storage tank whenever liquid gasoline was pumped into an automobile’s tank. If the nozzle spout failed to seal tightly during operation, the suction power was kept at a minimum. The vacuum assist recovery device was equipped with an independent vapor recovery pump, which actively captured the escaped gasoline vapor even when the seal of the nozzle boot was not tight. In March 1997, the Environment Protection Administration (EPA) of Taiwan provided a fiscal incentive for the installation of vacuum assist recovery devices. The devices must be certified with a recovery efficiency of at least 90% by the weight of gasoline vapor displaced during the dispensing of gasoline. In one study from 1997 to 2000, the personal air sampling of workers performing gasoline sales under vacuum assist recovery devices showed a general decrease in solvent exposure down to one half or even lower (Chen, 2002).

3. Result

In the petrochemical company under study, there were a total of 992 cases of occupational injuries (including mor-

Table 1

Number, age, and employment durations of workers in the petrochemical company stratified by gasoline exposure

Periods	Exposed ^a	Non-exposed ^b
Number of workers (% male)		
1991–1992	13088 (93%)	14294 (88%)
1993–1996	25135 (93%)	28445 (88%)
1997–2000	22520 (92%)	27185 (89%)
Age (mean $\pm$ S.D.) (years)		
1991–1992	39.3 $\pm$ 8.3	39.2 $\pm$ 8.6
1993–1996	41.8 $\pm$ 8.2	41.3 $\pm$ 8.4
1997–2000	45.0 $\pm$ 8.4	44.5 $\pm$ 7.9
Duration of employment (mean $\pm$ S.D.) (years)		
1991–1992	14.5 $\pm$ 7.6	13.5 $\pm$ 8.8
1993–1996	17.1 $\pm$ 7.6	15.7 $\pm$ 8.7
1997–2000	20.5 $\pm$ 7.4	18.9 $\pm$ 8.4

^a Exposed: gasoline sale division.

^b Non-exposed: administration, refinery, petroleum exploration, and research & development divisions.

tality) during 1991 to 2000. Among those cases, 626 cases were caused by traffic injuries: 555 male and 71 female workers. After excluding 108 cases that belonged to other divisions, there were 253 and 265 cases of traffic injury in the gasoline-exposed group (gasoline sale division) and gasoline-unexposed (administration, refinery, petroleum exploration, and research & development divisions), respectively.

With all the three periods under Table 1, the demographic data showed no major differences in age distribution and durations of employments between the exposed and non-exposed groups. Summarized in Table 2, there was a similar trend of reduced CIR for traffic injuries occurring in transportation to work for both the exposed and non-exposed groups during years 1991–2000. However, such a trend was only found in the exposed group for CIR of the way-back-home traffic injury, which seemed to correspond with the

periods of setting up more efficient gasoline recovery devices. In fact, the CIR on the journey back home dropped down nearly three times throughout the years. In Table 2 if counted by a human capital cost per worker per year, the reduction amounted to about 25.2 and 21.5 times decrease of potential person-days and salary loss due to the way-back-home traffic injury in the division of gasoline sales after establishing different vapor recovery devices. In other words, the average potential person-day and salary lost were 4.03 days and 7029 New Taiwan dollars (NTD; US\$ 1 = 34 NTD) per person per year during 1991 and 1992, and dropped down to 0.65 days, 1849 NTD, and 0.16 days, 327 NTD, respectively, after the installment of two different types of gasoline vapor recovery devices. There also seemed a decline of costs due to the on the way-to-work traffic injury; however, to a lesser degree and with no consistent trend.

With the incidence rates of traffic injuries in the non-exposed group as the denominators, the RRs and 95% confidence interval (CI) for the exposed group were calculated and were summarized under Table 3. The results showed that the RR for the total traffic injuries dropped from 1.61 (1991–1992) to 1.14 (1993–1996), and to finally 0.83 (1997–2000). Such a consistent trend was seen in the gasoline sales division for both genders and combined. The RR for on the way-back-home traffic injuries dropped from 2.39 to 0.81 during the first period, and then further dropped down to 0.47. Such a trend persisted after stratification for male and female workers. There was an elevated risk of traffic injuries during the job for the period of 1993–1996, but it came down in the same trend after the period of 1997–2000 when more effective control devices were installed. To control potential confounding variables by different traffic conditions and law enforcements, the data were stratified into different regions of sales, which still showed the same trend of decreasing traffic injuries for the exposed group during the study period.

Table 2

Cumulative incidence rate (CIR) and potential salary loss (PSL) in New Taiwan dollars (NTD) (US\$ 1 = 34 NTD) and potential person-days loss (PPDL) per person per year (figures in parentheses) due to traffic injuries stratified by exposure to gasoline, three time periods, and occupational settings of occurrence

Places of traffic injuries	Periods	CIR (number of observed cases)		PSL and PPDL (figures in parentheses)	
		Exposed ^a	Non-exposed ^b	Exposed ^a	Non-exposed ^b
Way-to-work traffic injuries	1991–1992	0.152 (44)	0.116 (35)	1147 (0.72)	59 (0.04)
	1993–1996	0.147 (45)	0.089 (61)	950 (0.55)	1906 (1.06)
	1997–2000	0.109 (34)	0.048 (42)	216 (0.13)	292 (0.08)
On-job traffic injuries	1991–1992	0.027 (7)	0.018 (7)	607 (0.38)	9 (0.00)
	1993–1996	0.049 (29)	0.015 (8)	621 (0.31)	81 (0.02)
	1997–2000	0.049 (12)	0.023 (14)	756 (0.32)	5 (0.00)
Way-back-home traffic injuries	1991–1992	0.157 (33)	0.043 (15)	7029 (4.03)	604 (0.35)
	1993–1996	0.094 (36)	0.110 (50)	1849 (0.65)	185 (0.08)
	1997–2000	0.050 (13)	0.097 (33)	327 (0.16)	162 (0.08)
Total traffic injuries	1991–1992	0.305 (79)	0.168 (55)	9044 (5.13)	672 (0.39)
	1993–1996	0.266 (109)	0.202 (119)	3420 (1.51)	2172 (1.16)
	1997–2000	0.195 (59)	0.160 (89)	1299 (0.61)	459 (0.16)

^a Exposed: gasoline sale division.

^b Non-exposed: administration, refinery, petroleum exploration, and research & development divisions.

Table 3

Rate ratios (RR) and 95% confidence intervals (CI) calculated by comparing the injury rates between the exposed^a with the non-exposed^b groups stratified by gender

Periods	Gender	Way-to-work traffic injuries		On-job traffic injuries		Way-back-home traffic injuries		Total traffic injuries
		No. ^c	RR [95% CI]	No. ^c	RR [95% CI]	No. ^c	RR [95% CI]	RR [95% CI]
1991–1992	Male	37	1.24 [0.77–1.99]	6	0.89 [0.30–2.64]	27	2.15 [1.11–4.17]	1.43 [1.00–2.05]
	Female	7	3.03 [0.89–10.3]	1	3.46 [0.12–103]	6	3.46 [0.87–13.8]	4.11 [1.58–10.3]
	All	44	1.37 [0.88–2.13]	7	1.09 [0.18–3.10]	33	2.39 [1.30–4.41]	1.61 [1.15–2.26]
1993–1996	Male	41	0.87 [0.57–1.31]	27	4.16 [1.81–9.54]	32	0.73 [0.47–1.15]	1.14 [0.86–1.51]
	Female	4	0.70 [0.22–2.22]	2	3.48 [0.32–38.4]	4	2.32 [0.52–10.4]	1.27 [0.57–2.87]
	All	45	0.83 [0.57–1.22]	29	4.09 [1.89–8.94]	36	0.81 [0.53–1.25]	1.14 [0.88–1.49]
1997–2000	Male	31	0.99 [0.62–1.61]	11	1.06 [0.47–2.40]	12	0.53 [0.27–1.06]	0.83 [0.58–1.18]
	Female	3	0.87 [0.22–3.48]	1	0.87 [0.08–9.60]	1	0.25 [0.03–2.02]	0.95 [0.40–2.25]
	All	34	0.97 [0.62–1.53]	12	1.03 [0.48–2.22]	13	0.47 [0.25–0.90]	0.83 [0.60–1.15]

^a Exposed group: gasoline sale division.

^b Non-exposed group: administration, refinery, petroleum exploration, and research & development divisions.

^c Number of observed cases for exposed group.

4. Discussion

This study showed that the CIR and the human capital cost on the way-back-home traffic injuries in the gasoline sales division (gasoline-exposed) decreased during the whole period between 1991 and 2000. Additionally, two declining events also occurred from 1993 to 1996 and 1997 to 2000, which seemed to correspond with the installment of two different types of gasoline vapor recovery devices during the two time periods. Although this observation did not necessarily imply that such a decrease was caused by the gasoline recovery devices, additional arguments below helped clarify that the reduction of gasoline exposure was probably the main reason.

Since the contrasts of exposure, age distribution, and duration of employment between the exposed and non-exposed groups were relatively clear, the main difference was gasoline exposure as shown in Table 1. The self-comparisons for rates of pre- and post-shift and with the three time periods also corroborated strongly with the above hypothesis because of minimal potential confounding. This tendency persisted even after stratification by different traffic conditions at different sales regions. Moreover, such a tendency of a declining occurrence in the way back home only happened in the gasoline sales division in comparison to other divisions in this petrochemical company, which could exclude the possible contribution of the health promotion activities and other general occupational policies in this company. As shown in Table 2, the CIR of injuries on the way back home increased in the other divisions in the period of 1997–2000, and demonstrated that the trend of traffic injuries did not necessarily decline. Another possible reason for the reduction of RR was the increased CIR for the unexposed group during the late 1990s. However, after re-calculating the crude annual frequency rates to minimize the potential effects of small numbers in the several age strata, the results showed 1.05, 1.76, and 1.21 per 1000 worker-years for the three consecutive periods of 1991–2000. Compared with 2.52, 1.43,

and 0.58 of the gasoline-exposed group during the same periods, the reduction of RR seemed unrelated to the slight increase of the unexposed workers. The higher crash rates of the exposed workers on their journey to work were probably related to the psychological stress when workers were in a hurry to the worksites, as suggested by some injured workers. The incidence rates of way-back-home traffic injuries for the exposed group decreased significantly less than those in way to work, indicating that workers were generally more relaxed when they finished a full shift of work. This also seemed to correspond with the initial understanding of the regular working situation in the company under study. This study tentatively concluded that the reduction of frequencies and severity caused by traffic injuries on the way back home could be related to the installment of effective gasoline recovery devices.

The limitation of this study included no measurements on the air concentration of gasoline vapors for the workers. Thus, this study provided no recommendations for the occupational health standard of gasoline exposure. In addition, the study assumed that the recovery devices were installed immediately in all the service stations when stratified under the three time periods, but the assumption could have likely resulted in a null association instead of an overestimation of the results. Since there were additional part-time or short-term employees assisting the gasoline services, especially in metropolitan stations after 1982, the actual exposure of workers during 1991–2000 might be lower than before. Thus, the injury rates and costs probably underestimated the impact of gasoline vapor exposures.

Although the workmen compensation laws in some countries (e.g., France, Germany, Austria, and Taiwan) have explicitly included traffic injuries from commuting to and from work as part of occupational injuries, many other countries (e.g., Denmark and United Kingdom) lacked this type of system. Besides, the definitions of commuting accident varied in many countries where the commuting injury was fully compensated. Although compensation was payable

when traveling on transportation provided by employers in some countries (e.g., Singapore and Russian Federation), the commuting accident happening on public transportation or private car was not recognized as an occupational injury. This study has shown that occupational exposure to volatile organic compounds, such as gasoline, might have increased the chances of traffic injuries for workers on their journey back home. According to the concept of “out of work”, the employer should be responsible for such an increased risk. Thus, this study recommended that employers should implement comprehensive occupational health practices to control and reduce the worker’s exposure to organic solvents, and in addition the compensation law should be modified in the future to compensate traffic injuries on the way back home for workers exposed to gasoline and/or solvents.

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