App. Envi. Res. 39(1) (2017): 23-32

Applied Environmental Research

Journal homepage : http://www.tci-thaijo.org/index.php/aer

Prevalence of Fatigue and Its Determinants among Chemical Transportation Drivers in Chonburi

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Article History
Submitted: 13 July 2016/ Accepted: 19 August 2016/ Published online: 15 February 2017

Abstract

Driver fatigue is a recognized risk factor for commercial road transport industry drivers. The aim of this cross-sectional research was to assess the fatigue and its determining factors among 99 chemical transportation drivers in Chonburi. Driving fatigue was assessed by both subjective questionnaire (n = 99) and flicker fusion instrument (n = 88). The association between driving fatigue and related factors were analyzed by Pearson's correlation and Chi-square (χ^2). The results revealed that the prevalence of fatigue as assessed by critical flicker fusion analyzer, subjective fatigue question and either one of the instruments were 32.32 %, 16.16 % and 43.43 %, respectively. Multiple regression analysis indicated that the predictive factors of objective fatigue were alcohol drinking, musculoskeletal disorder and road accident history. The results suggest that screening for alcohol use and musculoskeletal disorders was further needed for policy settings and routine checks.

Keywords: Chemical transportation; Determinants; Drivers; Fatigue

Introduction

The industries and economies of nations depend, in part, on the large numbers of hazardous chemicals transported from the producer or supplier to the user and, ultimately, to the waste disposer. Road traffic injury is listed in the top ten major causes of mortality and morbidity worldwide [1]. Chonburi is one of the most important industrial centers, logistic facilities and tourist cities of Thailand. It is the only province outside of the Bangkok Metropolitan Area that is connected by an eight-lane motorway to Bangkok. Up to 20 % of all road accidents occur on major roads and motorways [2]. Chemical road transport is considered a major cause of environmental health, social and economic consequences. For example, in 1990, an accident caused a gas tanker to explode on New Phetchaburi Road in Bangkok, killing 90, injuring 90 and destroying 43 vehicles. It was one of the deadliest man-made disasters in Thailand, until a year later, in 1991, a dynamite truck crashed in Phang Nga Province, killing 202 people and injuring 525. From 2010 to 2014, a total of 9 people have died and 78 injured directly during road transportation of hazardous chemicals [3].

In today's driven society, fatigue has become a major problem in occupational activities. Fatigue is defined as an impairment of mental and physical function manifested by a cluster of debilitating symptoms, usually including excessive sleepiness, reduced physical and mental performance ability, depressed mood and loss of motivation. Driver fatigue results from road traffic activity in an environment of five basic elements including driver, vehicle, road traffic, road and its environment. It has long been identified as a major cause of road accidents due to reduced performance [2, 4]. Out of 100 responding New Zealand truck drivers (out of 600 surveyed) at depots, wharves, markets, and other locations throughout the North Island found that 24 % of drivers reported starting work in a fatigued state, while 39 % reported becoming fatigued while driving [5].

Driving a chemical vehicle is becoming increasingly more difficult especially in metropolitan and suburban areas of Chonburi. The public is becoming much more aware of and concerned with the dangers involved in hazardous chemical transportation. The purpose of this study was to assess both fatigue and also identify all risk factors related to fatigue among chemical transportation drivers in Chonburi province. The research outcomes provide meaningful results that may be used to inform public policy and preventive strategies.

Materials and methods

1) Sampling sites and study population

Chonburi, an eastern province of Thailand, was selected as a research case study. Three types of chemical industries were considered (F1: Painting industry, F2: Industrial gas manufacturing, and F3: Flammable gas production). In this context, sampling locations were selected based on the following criteria: industry location, type of industry and other factors including the consent of plant managers and workers to conduct the research. Sampling sites were high risk chemical industries according to the attachment in the notification of Ministry of Industry No.3/2542 under Hazard Substances Act B.E. 2535 which are located in Chonburi. By considering the frequency of hazardous chemical transportation, three types of chemical industries suffering from frequent accidents involving gases and flammable liquids were selected as the sampling locations for our study [3]. Within these three industry categories, seven chemical factories were chosen, including two industrial gas manufacturing factories (i.e., O_2, N_2, He, Ar production and transportation), two flammable liquid factories, and three paint production factories. Then we did cluster sampling in each category of chemical industries. The description of these factories was presented as follows: F1: This factory is a paint industry located in an Industrial Estate. Transportation of hazardous chemical product is performed under the operation of contractor. F2: This factory manufactures industrial gases (non-flammable and non-toxic gases (i.e., O_2, N_2, and Ar) located in an Industrial Estate. F3: This factory manufactures flammable gas (Liquefied Petroleum Gas; LPG) located outside of an Industrial Estate area.

All 99 drivers at the three chemical industries participated in this study. As such, all participants were day-shift chemical drivers, who started work in the morning (06:00-09:00 a.m.) ending their shift in the evening (4:00-6:00 p.m.). There are two selection criteria for participants: (i) gender (only male) and (ii) driving experience (≥ 4 months; probation period). A consent form was signed before completing a questionnaire and other tests. This study was approved by the Ethics Review Committees for Research on Human Subjects, Burapha University.

2) Assessment of driver fatigue and its determinants

Driving fatigue was also assessed (both subjective and objective). Data on driver fatigue and its determinants were collected based on the results of questionnaire survey (subjective) and a flicker fusion instrument (objective).

The questionnaire was divided into two parts, the first to collect the respondent's general socio-demographic profile, work history (in terms of work experience, work duration, type of vehicle used and engine, global positioning system (GPS), accident history) and worker's health status (i.e., congenital disease, sleeping hours, vision impairment, musculoskeletal disorder, exercising, smoking, drinking of alcohol). The questionnaire was sent to 3 experts to verify the structure and content validity. Consistency was examined using Cronbach alpha coefficient, which was calculated to be 0.788. The second part contained subjective fatigue question using the Piper fatigue scale [6]. Subjective dimension of this study included driver's perceptions on the impact that fatigue has on daily activities (behavior dimension); emotional meaning attributed to fatigue (affective dimension); mental, physical and emotional symptoms of fatigue (sensory dimension); and mental action and understanding through thought and experience (cognitive dimension). It is a 22-item scale with four sub-scales: behavior (6 items), affect (5 items), sensory (5 items) and cognition/mood (6 items). Each item has 11 response categories on a 0 to 10 metric with verbal descriptors anchoring the endpoints. Each sub-scale is scored individually and then aggregated together for an overall score, with higher scores reflecting more fatigue. The subjective fatigue was classified into a 3-category response scale (0-3 = mild; 4-6 = moderate; 7-10 = severe fatigue).

Objective fatigue measurement was also conducted using a flicker fusion analyzer (CFF), model 12021A. The CFF offers several advantages: measurement is rapid and easy to perform; it is not influenced by the subject's motivation, and has a low rate of false positive results [7]. Measurements of the critical flicker frequency threshold was done by intrafoveal stimulation with a luminous diode, and measured in a quiet and semi-darkened room. When the eyes was not fatigued, they could be readily perceived to wink at a high frequency and critical flicker frequency value (CFF) will be high. The results of testing showed decreased values when visual fatigue occurred. Critical flicker frequencies were measured before and after driving for three times each and the mean value was calculated. The unit of critical flicker frequency was cycle per second or Hertz. Participants were categorized as presenting fatigue symptoms when ($CFF_{after} - CFF_{before}$) > 1SD of individual CFF_{before}. Because of the high variance among individuals, we assessed objective fatigue by using the standard deviation of each individual.

3) Statistical analysis

Data were analyzed using the Statistical Package for the Social Sciences (SPSS Inc. Version 17). The general socio-demographic information, work history (work experience, work duration, type of vehicle used and engine, global positioning system (GPS), accident history) and health status (sleeping hours, congenital disease, vision impairment, musculoskeletal disorder, exercising, smoking, drinking of alcohol, energy and coffee drinking) were analyzed by descriptive statistics. The associations between driving fatigue and quantitative factors were analyzed by Pearson correlation. The categories of driving fatigue (fatigue, no fatigue) and qualitative factors were analyzed by Pearson Chi-square (χ^2). Multiple regression was also used to analyze identifying factors affecting driving fatigue. Backward elimination was used to remove the least significant variable in the multiple regression models ($p \geq 0.10$). P-values less than 0.05 were reported as statistically significant.

Results and discussion

1) Personal factors and health status of workers

Of the 99 drivers, 53 (53.5 %) used GPS vehicle for chemical transportation and only 1 % used automatic gear vehicle. The drivers had mean age of 38.20 years (SD = 7.91, min-max=21-64 years), with mean body weight of 73.14 kg. Those with overweight indicated by BMI ac-counted for 62.6 %.

Health information of workers showed that 16 % of them suffered from congenital disease including gout, diabetes, asthma or allergy. 27 % of the participants had a history of visual abnormality and musculoskeletal disorder. Approximately 30 % of workers slept less than 7 hr and 40 % of them took no exercise. More than 50 % of them always drank caffeine and energy drinks. Alcohol drinking was found in 21.2 % of respondents (data not shown). The analytical results indicated that the most significant health factor associated with $CFF_{aft-bef}$ was alcohol drinking (Table 1).

2) Work factors of drivers

The mean work experience of the drivers was 5.37 years (SD = 6.47, min-max=0-32 years). The distance of driving per day was averaged to be 156.45 km with a mean driving hours of 6.13 h d^{-1}. About 97 % of workers had been trained in chemical and road safety; however, 53.4 % of drivers had previously been involved in road traffic accidents. Within this sub-group, about 10 % of drivers covered a distance of more than 400 km per day and worked overtime more than 19 hours per week. Although long working hours is identified as one of the main risk factors of accidents involving drivers, it did not show a significant effect on CFF value. This was in contrast to a previous report, which found 12-h day shifts were linked with greater fatigue [8]. Our study found no significant differences between work factors and $CFF_{aft-bef}$ ($p>0.05$) (Table 2).

3) Prevalence of driver fatigue

CFF is reliable, simple, easy to apply technique, which is not influenced by age or education level. CFF is a well-established neurophysiological technique that measures the ability of the central nervous system to detect flickering light [9]. The results revealed that the prevalence of fatigue as assessed through critical flicker fusion analyzer, subjective fatigue questions or by either one of the instrument were 32.32 %, 16.16 % and 43.43 %, respectively (Table 3). The mean value of objective fatigue before starting work (CFF_{bef}) was 39.12 Hz (SD = 3.20, range=29.33-48.03) and of after work (CFF_{aft}) was 37.76 Hz (SD = 4.29, min-max=23.23-44.30) whereas mean value of subjective fatigue was 3.13 (SD = 0.99, min-max = 1.09-6.45). Fatigue is defined as a biological drive for recuperative rest and also non-inflammatory conditions [10-11]. In comparison with other studies, the prevalence of fatigue in chemical drivers (32.32 %) were lower than computer users (49.7 %) [12]. In the USA, the prevalence of fatigue syndrome varies according to the diagnostic criteria employed and the cohort investigated, and was found to be 0.23-0.46 % [13]. From agreement testing, we found that 47 out of 88 participants (53.41 %) showed the agreement among non-fatigue drivers both assessed through flicker fusion instrument and questionnaire, and 5 out of 88 participants (5.68 %) resulted in the agreement between the objective and subjective fatigue (data not shown). Overall, the results showed the agreement testing at 59.1 %. This finding was in contrast to previous reports indicating that subjective fatigue did not reflect the objective physiological status of the tired person because of bias in motivation, personal factors experience, training, etc. [14]. In a review of long working hours, van der Hulst [15] concluded that subjective, rather than objective, measures are more commonly linked to fatigue.

Table 1 The objective fatigue classified by personal information and health status

Parameters	Driver Fatigue		Critical Flicker Fusion ($CFF_{aft-bef}$)					
	Number	**%**	**Mean**	**SD**	**Median**	**Min**	**Max**	**P-value**
Age (years old)								
21-30	13	14.8	-2.04	1.79	-2.06	-5.13	1.53	0.568
31-40	38	43.2	-3.30	3.91	-2.13	-15.83	1.30	
41-50	31	35.2	-3.08	2.15	-3.13	-6.23	2.53	
> 50	6	6.8	-3.98	4.72	-2.71	-13.20	-0.20	
Body Mass Index (BMI)								
Normal	30	34.1	-3.00	3.97	-2.11	-15.33	2.53	0.853
Overweight	58	65.9	-3.13	2.71	-2.71	-15.83	0.60	
Sleeping hour								
< 7	23	26.1	-3.60	2.45	-3.00	-9.03	0.00	0.371
≥ 7	65	73.9	-2.91	3.39	-2.20	-15.83	2.53	
Congenital disease								
No	74	84.1	-2.98	3.17	-2.51	-15.83	2.53	0.470
Yes	14	15.9	-3.65	3.26	-2.33	-13.20	-0.87	
Vision impairment								
No	26	29.5	-3.23	3.07	-2.21	-13.20	2.53	0.772
Yes	62	70.5	-3.02	3.24	-2.97	-15.83	1.53	
Musculoskeletal disorder								
No	63	71.59	-3.00	3.25	-2.63	-15.83	2.53	0.690
Yes	25	28.41	-3.30	3.03	-2.16	-13.20	0.57	
Exercise								
No	29	33.0	-3.64	3.97	-2.63	-15.83	0.70	0.252
Yes	59	67.0	-2.81	2.70	-2.40	-15.33	2.53	
Smoking								
No	53	60.2	-3.34	3.57	-2.70	-15.83	1.30	0.349
Yes	35	39.8	-2.69	2.45	-2.20	-9.03	2.53	
Alcohol drinking								
No	20	22.7	-4.78	3.94	-4.28	-15.33	-0.20	0.006*
Yes	68	77.3	-5.29	2.75	-2.18	-15.83	2.53	
Energy drink								
No	24	27.3	-3.33	2.90	-2.78	-13.20	0.57	0.663
Yes	64	72.7	-3.00	3.28	-2.37	-15.83	2.53	
Coffee drinking								
No	24	27.3	-2.84	3.69	-2.13	-15.33	0.70	0.660
Yes	64	72.7	-3.18	2.98	-2.57	-15.83	2.53	

Table 2 The objective fatigue classified by work factors

Parameters	Driver Fatigue		Critical Flicker Fusion ($CFF_{aft-bef}$)					
	Number	%	Mean	SD	Median	Min	Max	P-value
Work year experience								
≤ 1	31	35.23	-3.46	4.01	-2.40	-15.83	1.53	0.408
> 1	57	64.77	-2.87	2.62	-2.50	-13.20	2.53	
Work hours per day								
≤ 8	60	68.2	-3.26	3.36	-2.66	1.30	-15.83	0.464
> 8	28	31.8	-2.72	2.75	-2.26	2.53	-9.03	
Work hour overtime per week								
≤ 8	49	55.6	-3.40	3.26	-3.00	1.30	-15.33	0.760
> 8	13	14.8	-2.04	2.09	-1.30	0.70	-6.17	
Type of vehicle								
Pick-up 4 wheel	35	39.8	-2.77	2.59	-2.20	1.30	-13.20	0.669
6-wheel truck	13	14.8	-3.28	2.69	-3.00	0.60	-9.47	
10-wheel truck	18	20.5	-3.86	4.92	-2.36	1.53	-15.83	
> 10-wheel truck	22	25.0	-2.85	2.53	-2.10	2.53	-7.83	
GPS								
No	45	51.1	-2.92	2.65	-2.63	1.30	-13.20	0.612
Yes	43	48.9	-3.26	3.67	-2.40	2.53	-15.83	
Type of engine								
Automatic gear	87	98.9	-3.12	3.18	-2.50	2.53	-15.83	0.363
Manual gear	1	1.1	-0.20	-	-0.20	-0.20	-0.20	
Accident history								
No	41	46.6	-2.83	3.55	-1.97	2.53	-15.83	0.478
Yes	47	53.4	-3.31	2.83	-3.00	1.53	-13.20	

Table 3 Prevalence of driver fatigue assessed through flicker fusion instrument and subjective fatigue questionnaire

Instrument	Number	%	95 % CI
Flicker fusion analyzer	32	36.36	(-7.26) - (-4.95)
Subjective fatigue questionnaire	16	16.16	4.42 - 5.14
Flicker fusion analyzer or subjective fatigue questionnaire	43	43.43	(-6.17) - 3.98

4) Multiple regression models of variables effecting on fatigue

The multiple regression analytical results showed that factors determining the objective fatigue included alcohol drinking, musculoskeletal disorder and road accident history. Alcohol drinking and musculoskeletal disorder had a negative effect or produced more fatigue whereas accident history (i.e. no accidents within the past year) had a positive effect (decreased fatigue). The equation could explain the variability of CFF value at 40.3 % (Table 4).

These findings are inconsistent with previous reports indicating that a higher rate of work-related fatigue was associated with age and work experiences. Older drivers, one of the most critical driver population segments in the future, are more susceptible to fatigue and are more vulnerable to serious road injury and death in the event of a traffic crash [16-17]. Young drivers are part of the high risk group because of their lack of experience or knowledge how to handle fatigue and failure to understand potential threats or overestimating their ability to drive [18-22]. However, more experienced drivers continue driving when feeling fatigued, and try to fight it [2, 23]. Although more fatigue was found among overweight drivers, BMI did not appear to significantly affect value. They were more frequently involved in sleepiness-related road accident, especially at night. The elevated BMI, which is common in shift and transport workers, is a risk factor for obstructive sleep apnea that results in significantly compromised sleep quality and consequent daytime fatigue [18].

Table 4 The variable coefficient and critical flicker frequency value (CFF) analyzed by multiple regression

Variables	β	SE	t	p	95 % CI
Alcohol drinking	-1.560	0.567	7.562	0.006	0.069 - 0.639
Musculoskeletal disorder	-1.681	0.835	4.052	0.044	0.036 - 0.957
Work year experience	-0.090	0.047	3.672	0.055	0.883 - 1.002
Accident history	1.708	0.872	3.832	0.050	0.998 - 0.487

Note: R^2 = 0.403

Smoking, exercise and congenital disease were not found to have no significant effect on driver fatigue, in contradiction to the findings of Boonpa [19] who found significant influence of smoking, exercise and congenital disease on fatigue among bus drivers of Bangkok Mass Transit Authority. In that study, shortened sleep routinely result in increased sleepiness and fatigue during the waking hours [20]. Sleep disorders were also found to be confounding factors of fatigue [11]. However, in our study, sleep deprivation did not significantly affect driver fatigue.

In this study, the multiple regression analysis showed that visual impairment did not affect driver fatigue levels, again in contrast with previous studies which showed vision, cognition and motor functions influenced fitness to drive. They are after all the three key functions required for safe driving [21-22]. Although a driver needs to be physically, mentally, medically and functionally fit in order to operate a vehicle, these factors are not evaluated by licensing authorities in Thailand.

We neglected socio-economic status variables of education and income which are often statistically linked and typically interact strongly with other demographic variables, such as type of work position and overtime work. In general, studies suggest the fatigue of lower socio-economic status employees is more likely to be allied with longer working hours (including overtime) and higher physical workload, while that of higher socio-economic employees is more likely to be associated with managerial work manifesting as mental fatigue [24].

Fatigue is as common and severe as pain in musculoskeletal conditions [25]. In this study, drivers who had musculoskeletal disorders were found more fatigued. This was in agreement with the findings of Repping-Wuts [26] who reported significant influence of musculoskeletal disorder on driver fatigue. Other symptoms e.g. poor mood, stress, sleep disruption were also found among people with rheumatoid arthritis and osteoarthritis [27]. Driver fatigue in our study was found to result from three main factors, i.e., alcohol drinking, musculoskeletal disorder and accident history, although other factors can clearly be involved [28-29]. In all 3 study sites, blood alcohol level is randomly measured by safety officers once a month. Some studies showed that subjects who had blood alcohol level 0.05 %, 0.08 % and 0.10 % produced driving performance decrement equivalent to those awake for 18.5, 21 and 24 hours of wakefulness [30-31]. This study found a strong and significant relationship between alcohol drinking and fatigue. This may further compound the accumulation of chronic fatigue across the work cycle. Accident history showed a positive effect or decrease fatigue. This may be linked to wider personality variables, such as obsession, depression, and introversion [32]. Although the topic of fatigue, accident risk and personality have been previously investigated, no studies known to us have specifically examined if and how driver crashes and personality traits might be associated with fatigue and driving crash risk [24]. Further research is required to better understand the attributes and constructs of fatigue and accident proneness as a potential basis for innovative preventive interventions.

Our results suggest that screening for alcohol dependence and musculoskeletal disorder was needed for new employees. Safety measures also required routinely any screening for alcohol use before and after driving. In addition, our results support the findings of the Medical Council of Thailand that disorders of the musculoskeletal system (i.e., rheumatoid arthritis, gout) directly affect driving ability. In this context, more research is needed to better understand the fatigue of night shift workers and also needed to examine rest break scheduling and the content of the break for improving road safety and contribute to an efficient and sustainable chemical transport system.

Conclusions

The results of this research revealed that the prevalence of fatigue as measured using the critical flicker fusion analyzer, subjective fatigue questionnaire and either one of the instruments were 32.32 %, 16.16 % and 43.43 %, respectively. Multiple regression analysis showed that factors affecting objective fatigue included: alcohol drinking, musculoskeletal disorder and road accident history. Alcohol drinking and musculoskeletal disorders exacerbated driver fatigue. On the other hand, drivers with an accident-free history of 1 year or longer showed reduced fatigue levels. The study is limited by the relatively small sample size and the fact that all participants were day-shift chemical drivers. Further investigations of rest break scheduling and content of the break resulting in improved driver performance, driver retention and road safety are recommended.

Acknowledgements

This project was partially supported by the National Research Council of Thailand. The authors thank Dr.Wanlop Jaidee and Mr.Narin Krajaiklang for their valuable advice on statistical analysis. We also thank all the volunteers who participated in this study.

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