

# REVIEW ARTICLE

## Risk Factors of Fatigue: A Systematic Review Among Transportation Drivers

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### ABSTRACT

Fatigue is an inevitable problem in the workplace due to many factors. Transportation workers are susceptible to falling asleep at the wheel, feeling tired and drowsiness, prolonged mental and physical exertion, sleep deprivation, which will later result in fatigue. The objective of this paper is to provide a comprehensive review of driver fatigue, documenting potential relationships between demographics and work factors with prevalence of risk factors among transportation drivers. Related literature search was done using PubMed, SCOPUS, and ScienceDirect to review some articles related to factors influencing fatigue among transportation workers which was published between years 2000 to 2021. The most significant risk factors were poor quality and quantity of sleep, prolonged driving in a day and work-related factors. Therefore, further research should be directed towards assessing and implementing a standardized measurement of work fatigue. This could help the industry in precisely managing and measuring fatigue and sleepiness.

**Keywords:** Fatigue, Risk factors, Transportation and professional drivers

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### INTRODUCTION

In Malaysia, a study by the Malaysian Institute of Road Safety Research (MIROS) reported that fatigue is one of the biggest cause of crashes involving cars, lorries, and buses. Besides that, another study by MIROS among commercial truck drivers in Klang Valley reported that about 17.7 % of them were fatigued (1). Fatigue and drowsiness have been identified as the main risk factor for road accidents and fatalities.

Fatigue can be defined in different ways, but generally, fatigue is a state of reduced physical or mental alertness that impairs the performance of a range of cognitive and psychomotor tasks, including driving. Fatigue is

also understood as a suboptimal psychophysiological condition caused by exertion. Fatigue is generally divided into a few dimensions, including physical fatigue, cognitive fatigue, emotional fatigue. A fatigued individual lies between being asleep and alarm, hence the physical changes that occur may include reduced eye movement, brain activity, and muscle response. Cognitive fatigue impairs alertness, concentration, and attention, while emotional fatigue refers to emotional depletion or exhaustion, cognitive disengagement, and reduced motivation (2).

In the transportation industry, fatigue is known as one of the work-related hazards that can be linked to road crashes and fatalities, particularly in long-haul transportation drivers. Driving fatigue is considered to be more serious among professional drivers, such as truck drivers, because they are vulnerable to sleep loss, prolonged driving, circadian rhythm disruption as well as working stress related with high time pressure journey

(3). In-depth, driver physiological conditions, workplace conditions, environmental factors, demographic factors, and driving experience are the contributors to fatigue and sleepiness that can result in road crashes and accidents (4).

Numerous studies focused on fatigue and drivers have been carried out across the world, including in the US (5), Europe (6), Australia (7), Singapore (8), China (9), Korea (10), India (11), as well as Malaysia (12). Fatigue significantly increases reaction time and impair driving performance. A gradual loss in reaction time, vigilance, alertness, and concentration are the effects of sleepiness while insufficient sleep can lead to excessive fatigue, hypovigilance, stress and impairment of attention, speed of processing information, and quality of decision-making (13). Therefore, this present study is going to investigate the risk factors of fatigue drivers in transportation industry.

## METHODOLOGY

Comprehensive and systematic electronic searches designed, refined, and conducted using relevant articles related to the risk factor of fatigue on transportation workers were strategically searched for in PubMed, ScienceDirect, and SCOPUS. The search term was executed using keywords such as “fatigue”, “risk factor” in combination with “transportation drive” and/or “truck drive” published from 2000 to 2021. Studies deemed eligible to be included were articles published in the English language. The eligibility of studies was based on the relevance to fatigue risk factors among transportation drivers. The search used the following terms to exclude abstracts on disease, healthcare, and physician.

Initial screening was done to put together all the potential studies based on their titles and abstracts. These studies were then filtered after a full review of the article text and removing duplicates. We screened the reference list of reviews identified through the bibliography database search and of primary studies meeting the selection criteria below, then consulted content experts in identifying other potentially relevant studies.

## FINDINGS

For literature searching, the following inclusion criteria had to be fulfilled; 1) the article was written in English 2) articles published in peer-reviewed journals between 2000 and 2021 3) licensed and professional drivers

4) outcome measures reported at least one risk factor of fatigue. The studies represent research conducted nationwide including eleven from Asia, five from Europe and one from USA, Canada, Colombia and Serbia based on the affiliation of the first authors.

The result of the literature search is compiled in Table 1. A total of twenty studies are included in the analysis. A breakdown of the articles revealed that having poor sleep (eight articles) is the most common risk factor of fatigue among transportation drivers, followed by prolonged working hours (seven articles). Work factors such as time of the day (four articles), job stress and working pressure (three articles), poor health (two articles) and working experience (one article) are also factors that contribute to fatigue. All the publications were cross-sectional (nineteen articles) except one case control study. The prevalence of fatigue varies between 20 and 91 %. Next, thirteen studies used the questionnaire method to collect data, whereas six studies collected data using interview and two studies used focus group discussions. Participants in this study were transportation drivers that comprised truck drivers (nine articles), professional drivers (four articles), commercial vehicle drivers (three articles), heavy vehicle drivers (two articles), freight driver (one article) and taxi driver (one article).

On the topic of fatigue among transportation drivers, the electronic database cited 800 articles. After eliminating the studies that did not meet the selection criteria, we included twenty published articles in this paper (Fig. 1).

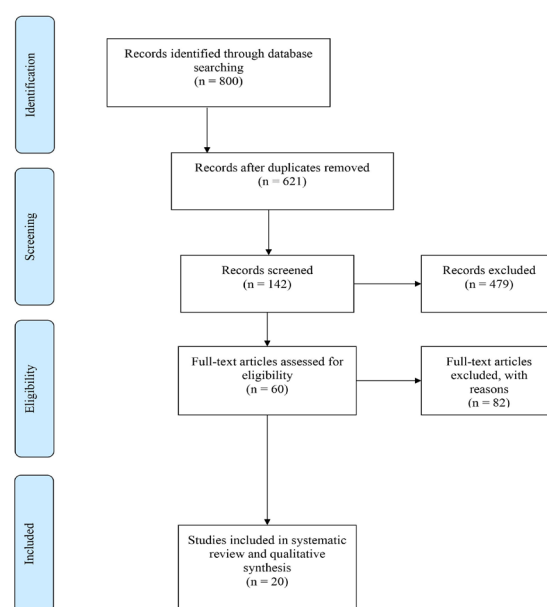


Fig 1: The PRISMA flow diagram

**Table 1: Factors associated with drivers' fatigue**

Authors and Year of Publication	Nation	Study design	Participants	Sample size	Method	Prevalence	Risk Factors	Statistical Analysis	Summary
Buczaj et al., 2021 (36)	Poland	Cross-sectional	Professional drivers	398	Interview	89%	Working experience	Working experience is significantly associated with fatigue ( $p < 0.05$ )	The most common symptoms of fatigue reported including drowsiness, eye strain, lack of concentration and lack of energy.
Iridiastadi et al., 2020 (37)	Indonesia	Cross-sectional	Commercial drivers	9	1) Questionnaire 2) Psychomotor Vigilance Task (PVT)	-	Driving hours	Blink rate was significantly associated with subjective rating of fatigue ( $p < 0.05$ )	Long-duration driving induced fatigue
Kwon et al., 2019 (10)	Korea	Cross-sectional	Commercial vehicles	161	Questionnaire	50.9%	1) Excessive daytime sleepiness (EDS) 2) Poor mental health 3) High perceived of fatigue	Working longer than 12 hours and EDS ( $p < 0.05$ )	ESS has been identified as both risk factors for accident risk index score and risky driving behaviour while poor sleep is associated with road crash
Teresa et al., 2019 (38)	Poland	Cross-sectional	Professional drivers	45	Questionnaire	13%	Duration of work shift	The level of fatigue was significantly higher after driving on heavy traffic route ( $P < 0.005$ )	Climate parameters such as ambient temperature, air pressure, humidity and wind speed and can modify the drivers' fatigue.
Cardoso et al., 2018 (39)	Canada	Cross-sectional	Truck drivers	20	1) Questionnaire 2) Simulation	-	Prolonged driving task	Drivers was significantly associated with muscular fatigue ( $p < 0.05$ )	Seat interactions had a significant effect on fatigue development
Davidovic et al., 2018 (6)	Serbia	Cross-sectional	Professional bus and trucks drivers	345	Questionnaire	-	1) Poor quality of sleep 2) Work factors	There is a statistically significant between hours of sleep and quality of sleep ( $p < 0.001$ )	Having poor sleep quality is the most significant influences towards fatigue and health factors is not association with fatigue.
Useche and Cendales, 2017 (26)	Spain	Cross-sectional	Professional drivers	524	Questionnaire	43.4%	Job stress	Fatigue level is significantly associated with job stress ( $F(1,418) = 109.44$ ; $p < 0.01$ ).	Fatigue is known to be significant associated with job stress and health complaint (diabetes, high cholesterol level ergonomic disorders).
Chen and Zhang, 2016 (40)	China	Case control	Truck drivers	9168	Interview	91.41%	1) Gender 2) Age 3) Driving experience 4) Vehicle type 5) Brake performance 6) Time of the day	Young (OR: 0.663), less experienced (OR:4.787) and male (OR:0.565) truck drivers are more likely to involve in fatigue crashes	Individual factors, vehicle factors and environmental factors are the contributing risk factors of fatigue-related crashes

CONTINUE

**Table 1: Factors associated with drivers' fatigue (CONT.)**

Authors and Year of Publication	Nation	Study design	Participants	Sample size	Method	Prevalence	Risk Factors	Statistical Analysis	Summary
Lim and Chia, 2015 (8)	Singapore	Cross-sectional	Taxi drivers	340	Questionnaire	32.9%	1) Poor quality of sleep 2) long hours driving 3) Part-time job 4) Caffeinated intake	Fatigue and sleepiness were positively associated with poor quality of sleep, having additional part-time job, excessive consumption of caffeine and long hours of work ( $p < 0.05$ ).	Lower prevalence of fatigue may be contributed to decreased road accidents, decreased economic loss, better productivity.
Nantaporn et al 2015 (41)	Thailand	Cross-sectional	Transportation drivers	107	1) Questionnaire 2) Flicker fusion instruments	16.6%	Poor sleep quality	High risk group (slept $< 7$ hours) had higher level of objective and subjective fatigue compare to low risk ( $p < 0.001$ )	Subjective measurement is more feasible to implement for fatigue measurement.
Meng et al., 2015 (9)	China	Cross-sectional	Truck drivers and taxi drivers	560	Questionnaire	38%	Prolonged driving	Taxi drivers reported more fatigue than truck drivers ( $p < 0.001$ ).	Driver fatigue more prevalent among taxi drivers. It is estimated that around 60% of taxi drivers and 38% of truck drivers reported fatigue while driving
Yassierli et al., 2015 (42)	Indonesia	Cross-sectional	Truck drivers	54	1) Questionnaire 2) Physiological measurement 3) Critical Flicker Fusion (CFF) test	-	Time of the day	Night shift was significantly associated with fatigue development ( $p < 0.05$ )	Self-reported measurement of Karolinska sleepiness scale (KSS) and Critical Flicker Fusion (CFF) were reliable to measure fatigue development for drivers
Kamaliana et al., 2014 (43)	Malaysia	Cross-sectional	Heavy vehicle drivers	60	Questionnaire	50%	Lack of sleep	Ninety percent (90%) reported insufficient sleep, alcohol consumption (86.6%), adverse climate condition (86.7%) and drug consumption (80%) were associated with driving fatigue	Heavy vehicle drivers start experienced fatigue after 2 hours of driving and they reported body discomfort on shoulders and low back.
Torregroza-vargas et al., 2014 (44)	Colombia	Cross-sectional	Freight drivers	401	Interview	50%	1) Driving hours	The numbers of break taken was associated with fatigue-related crash ( $OR = 0.13$ ; $P < 0.05$ )	Numbers of stops during driving and the average time during breaks showed significant association with fatigue-related crashes
Mahbub et al., 2013 (27)	Bangladesh	Cross-sectional	Truck drivers	400	Interview Focus group discussion	83%	1) Working pressure 2) Non-stop driving 3) Traffic congestions 4) Alcohol influences	Working pressure and mal-nutrient food consumption were associated with fatigue among truck and cargo drivers ( $P < 0.05$ ).	Fatigue occurs due to many reasons and highly fatal not only to drivers but for owners, clients and society as well.

**Table 1: Factors associated with drivers' fatigue (CONT.)**

Authors and Year of Publication	Nation	Study design	Participants	Sample size	Method	Prevalence	Risk Factors	Statistical Analysis	Summary
Pia et al., 2011 (45)	Finland	Cross-sectional	Heavy vehicle drivers	683	Questionnaire	27.8%	1) Lack of sleep 2) Poor health	Drivers fatigue reported having difficulty in remain vigilant while driving than non-fatigued drivers $(\chi^2 = 78.35, df=2; P<0.001)$	Long working shifts and less sleep are the risk factors of fatigue and falling asleep at the wheels
Sabbagh, Friedman and Richter, 2005 (46)	Israel	Cross-sectional	Truck drivers	160	Interview	39.4%	1) poor sleep quality 2) Difficulty finding parking when tired	Fatigue and crashes were associated with poor sleep quality (OR = 2.9; $p<0.05$ ) and difficulty finding parking when tired (OR=3.7 and $p<0.05$ ).	The most determinants factors of fatigue are reported included length of work day, duration time spent away from work rest and work-rest pattern in a 24-hours.
Adam-Guppy and Andrew, 2003 (25)	Europe	Cross-sectional	Commercial drivers	700	Questionnaire	20%	1) Time of the day 2) Shift rotation	There was a positive association driving while tired and numbers of days worked ( $p<0.05$ )	The time before start the shift around 0700 is known to be higher-related fatigue problems.
McCartt et al., 2000 (5)	USA	Cross-sectional	Long-distance truck drivers	593	Interview	47.1%	1) Greater daytime sleepiness 2) More arduous schedule with less off-duty hours 3) Older and experienced workers 4) Poor sleep 5) Night-time driving	Six factors were found to be significantly associated with falling asleep at the wheels ( $p<0.01$ ).	Results of the study showed 25.4% of the truck drivers reported falling asleep at the wheel. Greater daytime sleepiness was found to be the most highly predictive of sleepiness at the wheels
Oron-Gilad and Shinar, 2000 (47)	Israel	Cross-sectional	Military trucks drivers	314	Focus group Interview	20%	Insufficient sleep	The most frequent symptoms were physical fatigue that include feeling sleepy and less concentrated, feeling bored and blurred vision ( $p<0.01$ ).	Drivers who were young, less experienced and lower military ranks that in mandatory services reported more vulnerable to fall asleep at the wheels

## DISCUSSIONS

### Sleep quality

It is widely agreed that many factors contribute to fatigue in the transportation sector with the most apparent and obvious being having poor quality and quantity of sleep (8, 10). Transportation drivers have been found to have more sleep disruptions, especially for those who are

working the night shift and extended working hours (14). Most studies have examined the link between poor sleep, sleepiness, and fatigue among drivers (5, 15). Another study conducted among commercial truck and bus drivers in Thailand (16) showed a strong relationship between drowsiness and accidents. Notably, the main cause of drowsiness is sleep deprivation. A study among the chemical transportation drivers found that

drivers who had slept less than seven hours reported poor sleep quality and experienced fatigue (17). The research suggested that drivers in a sleep-related crash are more likely to report fair and poor quality of sleep and insufficient nighttime sleep (18).

### Prolonged working hours

Sleep deprivation factors combined with extended working hours pose a greater risk of fatigue, thus causing fatigue-related accidents. Having poor quality of sleep is closely related to working factors such as prolonged working hours or prolonged wakefulness. Driving activity requires sustained attention for a longer time. Thereby, prolonged driving time is likely to be the most common risk factor among all (19, 37, 38, 39). Long driving times also may deteriorate fatigue factors such as the circadian rhythm effect, sleep deprivation, and cumulative fatigue effect. Such extended duration of working hours not only causes fatigue but affect rest periods as well. In Canada, a research study on sleep and fatigue in the transportation industries showed that the most significant factor of sleepiness-related fatigue was the working hours (20). An experimental study by (12) found that prolonged driving had significantly induced higher fatigue levels, and thus deteriorated drivers' performance simultaneously. In another finding on an accident involving fatigue, commercial truck drivers were found to have slept an average of 5.5 hours during their last sleep compared to non-fatigue-related accidents, which had about 8 hours of sleep (21). However, factors like extended driving of more than 10 hours with regular short breaks did not affect the performance, but prior sleep loss significantly affected.

### Age

There are many possible risk factors of fatigue and fatigue-related accidents among transportation workers, including age factor. Generally, older age would develop fatigue in terms of reduced physiological and biological systems, vision alteration, thus leading to performance impairment, extended reaction time and muscle weakness (8). A study by (5) among long-distance truck drivers reported that higher fatigue-related accidents mostly occur among older and experienced drivers. This finding supported the evidence that older and experienced drivers had more accidents than younger drivers. The study among taxi drivers found that drivers aged above fifty years are significantly associated with fatigue and having poor sleep quality (8). On the other hand, young professional drivers were found to be more vulnerable to drowsiness and sleep-related accidents due to lack of alertness and sleepiness compared to middle-aged drivers as well as older drivers (22). Younger drivers among heavy commercial trucks were found to be significantly associated with a high risk of sleepiness; therefore, having higher risk towards road accidents (23). A similar result was discovered by (24) where younger drivers were more affected with fatigue compared to older drivers. The older group showed

greater stability of driving and less sleep deprivation. Meanwhile, a survey among commercial goods drivers indicated that there is no significant correlation between the age of drivers and fatigue experienced. Their finding indicated that time of day and shift rotation were the causes to fatigue problems (25).

### Work Factors

Work factors could be either working very long or having inadequate time to recover from work. These factors create adverse behavioural changes, for instance smoking, drinking, unhealthy diet as well as counterproductive work behaviour. Work stress also causes aberrant driving behaviours in the driver and have been largely found to be associated with road accidents (26). Arduous work schedule with less off-duty hours (5) that involve long working hours are also known to cause fatigue and signs of drowsiness among drivers. Apart from that, working pressure, non-stop driving and traffic congestion are the contributing factors to fatal accidents in Bangladesh (27). Traffic congestion was found to increase the level of driver fatigue, which is determined by the change of their functional state (28). This finding also confirms the other studies that show traffic congestion and time pressure predicted aggression, irritability, frustration, negative mood and nature of daily work strain leads to growing psycho-physiological responses (29). As would be expected, drivers do not get adequate break due to their strict and tight schedules. This continuous rotation puts great pressure on them and causes fatigue conditions at the wheels. Working experience was found to be a significant factor of fatigue (36). The fatigue group was found to be those who had been working for less than five years. Senior drivers with more experience reported less development of fatigue-related symptoms such as drowsiness, lack of concentration, irritability or eye strain.

### Time of the day

Another factor to consider is the time of the day that has been identified as predictive factors of fatigue among drivers. Generally, physiological alertness and vigilance deteriorate in two specific times in the day, which are afternoon post-punch dip between 1 to 4 pm and during nighttime between 4 to 6 am. A past study reported sleep-related accidents during this period (22). A study of fatigue among drivers has linked time of the day and fatigue as the most consistent factor (5, 14). Past researchers have identified nighttime driving among professional drivers resulted in reduced performance and alertness. This supported the fact that sleeping frequently occurs in nocturnal driving. Specifically, nighttime driving resulted in a high risk of sleepiness and fatigue for occupational drivers (30, 42). Fatigue-related accidents occur predominantly at night due to several factors such as circadian disruption and sleep restriction. For example, long-distance driving for eight hours during the night resulted in high numbers of errors



as compared to two hours of driving (31). A simulator experiment study by (32) compared between daytime driving and nighttime driving and the severity of driver fatigue showed a conclusion that long blink durations are associated with frequent line crossing during nighttime driving. In Japan, a study among long-haul heavy vehicle drivers found that working factors like night shift is one of the risk factors of accidents (33). However, there are a few confounders to consider, such as sleep duration, time awake, and prior sleep of the drivers that affect fatigue and drowsiness-related accidents (34).

### Other factors

Besides that, there are other factors to consider in relation to fatigue and sleepiness that includes body mass index (BMI), smoking, alcohol consumption, and vision. Individuals who fail to adapt with the circadian adaptation, especially during night work, will typically develop cumulative sleep debt that increases the risk of health problems, such as decreased glucose tolerance, which may in turn, lead to the risk of diabetes (35). In another finding, alcohol consumption showed a higher likelihood among Korean commercial drivers as compared to other types of jobs, such as the manufacturing or construction industries (10). In a previous study conducted by (15), truck drivers reported a high intake of alcohol. However, contrary to the expectation, it is concluded that alcohol consumption was found to have no significant association with sleepiness or quality of sleep.

### CONCLUSION

As a conclusion, many factors can affect drivers fatigue but the most significant risk are poor sleep quality and duration of work shift. Driving in sleepy condition brings to frequent mistake, the precision of the movement is reduced and reaction time is longer. The finding suggested that fatigue can be reduced by adjusting the pattern of work shift to prevent extremely long working hours to the drivers, and thus minimizing road crashes. Sleep quality and sleeping hours can be solved through optimization of the work-rest model and encouragement of drivers to stop and take a nap when they feel fatigued. Prolonged working duration with minimal rest breaks in between also contribute to the most significant factors of drivers' fatigue. The drivers who drove for extended shifts and less rest before is significantly associated with occurrence of a crash. Drivers entitled to have a break after 4 hours of continuous driving and driving duration should not exceed 9-hours as recommended by the International Labour Organization (ILO) (48). Fatigue risk management that integrate the elements such as fatigue reduction, sleep management, physical and mental health promotion to transportation drivers should be implemented.

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