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Original article

FATIGUE IN PROFESSIONAL DRIVERS – A RISK TO SAFE MOTOR VEHICLE OPERATION

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Abstract

Introduction: Fatigue is a major human factor affecting road safety, impairing attention, concentration, reaction time, and decision-making among professional drivers. This study examined the relationship between chronic fatigue and driving behavior in professional drivers.

Materials and methods: Between September 2020 and September 2021, a cross-sectional study was conducted in North Macedonia, including 210 professional male drivers (truck, bus, and taxi drivers). Data were collected using the Working Conditions and Workplace Questionnaire, the Checklist Individual Strength (CIS-20), and the Driver Behavior Questionnaire (DBQ). Statistical analyses included descriptive statistics, reliability testing and bivariate linear regression.

Results: The overall level of chronic fatigue was relatively low (CIS-20 score 1.81± 0.73); however, concentration was the most affected fatigue domain ($p<0.001$). Reduced concentration, motivation, productivity and overall chronic fatigue significantly predicted ordinary traffic violations. Reduced productivity showed the strongest association, explaining 18.9% of the variability in ordinary violations ($R^2=0.189$, $p=0.006$). Reduced concentration and overall chronic fatigue also significantly predicted driving omissions, whereas no significant association was found with aggressive violations or driving errors.

Conclusions: Chronic fatigue primarily affects cognitive aspects of driving, increasing ordinary traffic violations and omissions among professional drivers. Fatigue management strategies, including optimized work schedules, adequate rest, early diagnosis of sleep disorders, and targeted educational programs, are essential to improve road safety and reduce fatigue-related traffic accident.

Keywords: professional drivers, fatigue, driver behavior, road safety, traffic violations

Introduction

Road traffic safety depends on three key components: road infrastructure, vehicle condition and the human factor. Among these, the driver's psychophysical fitness is essential for safe vehicle operation.

Defining fatigue in professional drivers - In the context of driving, fatigue is a mental type of tiredness that results in impairment of cognitive and psychomotor functions in the driver, resulting in impaired attention, slower reaction time and poorer decision-making[1]. It has also been described as the transition from wakefulness toward sleep[2].

Fatigue in professional drivers arises from two major groups of factors: work-related and sleep-related[3]. Work-related fatigue develops under conditions of prolonged cognitive demands, heavy traffic, adverse weather, long driving hours and monotonous driving[4]. Sleep-related fatigue results from insufficient sleep, circadian rhythm disturbances and prolonged wakefulness, reducing alertness, particularly during evening and nighttime driving[5].

Fatigue represents a major road safety concern worldwide. Previous studies have shown that fatigue and sleepiness are important contributors to road traffic accidents, accounting for approximately 10–30% of crashes worldwide, depending on the definition and methodology used[6]. Approximately 60% of European truck drivers report having fallen asleep while driving, with similar findings reported in the United States, Australia and Ireland. Despite these alarming data, many drivers underestimate the risks associated with fatigue and overestimate their ability to continue driving safely[7,8]. The aim of this study was to examine the impact of chronic fatigue on professional drivers' traffic behaviour and to identify preventive measures that could improve road safety.

Materials and methods

Between September 2020 and September 2021, a cross-sectional study was conducted at the Institute of Occupational Medicine of North Macedonia. The study included 210 professional male drivers who voluntarily applied for an assessment of their fitness to operate motor vehicles.

The inclusion criteria comprised active professional truck, bus, and taxi drivers whose primary occupation involved commercial driving. Drivers holding professional driving licenses but not actively employed as professional drivers were excluded. Participation was voluntary and anonymous and all participants signed informed consent forms. Ethical approval was obtained from the Ethics Committee of the Faculty of Medicine, Ss. Cyril and Methodius University in Skopje. Three standardized questionnaires were used:

Working Conditions and Workplace Questionnaire, assessing demographic characteristics and occupational factors related to workload and work organization[9];

Checklist Individual Strength (CIS-20), evaluating chronic fatigue through four domains: subjective fatigue, concentration, motivation and productivity[10];

Driver Behaviour Questionnaire (DBQ), assessing aggressive violations, ordinary violations, omissions and driving errors[11].

Statistical analyses were performed using SPSS, version 20.0. Descriptive statistics, Shapiro-Wilk tests, ANOVA, Mann-Whitney U, Kruskal-Wallis, odds ratios, confidence intervals and bivariate linear regression analyses were applied. Internal consistency of the questionnaires was assessed using Cronbach's alpha coefficient. Statistical significance was established at $p<0.05$.

Results

The study included 210 professional male drivers with a mean age of 46.3 ± 9.5 years. Most participants had completed secondary education. Truck drivers represented the largest occupational group (63.3%), followed by taxi drivers (24.3%) and bus drivers (12.4%). No significant differences were observed among the occupational groups regarding years of service, weekly working hours or annual mileage. Most participants worked primarily in urban transport (64.3%), while smaller proportions were engaged in intercity (43.8%) and international transport (33.8%).

Chronic fatigue

Chronic fatigue was assessed using the CIS-20 questionnaire. Reliability analysis demonstrated excellent internal consistency, with an overall Cronbach's alpha of 0.928.

Reliability coefficients for the individual domains ranged from 0.657 to 0.916, confirming the validity of the questionnaire in this population.

The average overall CIS-20 score was 1.81±0.73, indicating generally low levels of chronic fatigue. However, significant differences were observed among the four fatigue domains ($p<0.001$). Concentration showed significantly poorer scores than both motivation and productivity, suggesting that concentration difficulties represented the most prominent manifestation of fatigue among professional drivers.

Table 1. CHIS-20 average total score analysis by domain

Individual Strength Checklist – CHIS-20						
CHIS – 20 domains (average total score)	**N**	**Aver.±SD Mean±SD**	**Min/ Max**	**Percentiles**		
				25th	**50th (Median)**	**75th**
Subjective feeling of fatigue	210	1.64±0.82	1/5.89	1	1.4	2
Concentration	210	2.10±0.82	1/6.00	1.6	2	2.6
Motivation	210	1.64±0.85	1/6.25	1	1.2	2
Productivity	210	1.86±0.87	1/6.67	1.3	1.7	2
Total	210	1.81±0.73	1/6.13	1.3	1.6	2.1
P	Kruskal-Wallis H test: $X^2(3)=75.716$; p=0.00001* Mann-Whitney U Test =Z S/C: Z=-7.171; p=0.00001*; S/M: Z=0.814; p=0.4156; S/P: Z=-3.699; p=0.0002*; C/M: Z=7.038; p=0.00001*; C/P: Z=4.127; p=0.00003*; M/P: Z=-4.178; p=0.00002*					

* significant for $p<0.05$

Driver behaviour

Driver behaviour was evaluated using the Driver Behaviour Questionnaire (DBQ). Reliability analysis demonstrated high internal consistency, with an overall Cronbach's alpha of 0.805. All four behavioural domains also showed acceptable reliability.

Significant differences were found among aggressive violations, ordinary violations, omissions, and driving errors ($p < 0.001$). Aggressive violations were the most frequently reported unsafe driving behaviours, whereas driving errors were the least common.

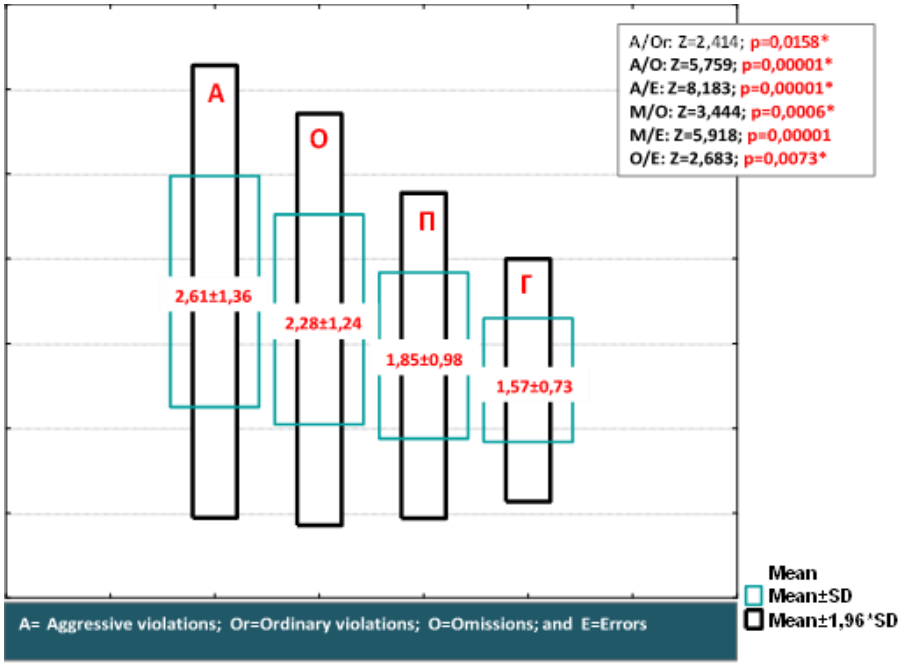

Fig. 1. Analysis of DBQ total average score by domain

Association between fatigue and driver behaviour

Regression analyses were performed to determine whether chronic fatigue predicted unsafe driving behaviour.

No significant association was found between chronic fatigue and aggressive traffic violations.

Table 2. Bivariate linear regression analysis of aggressive violations and domains of chronic fatigue and total CHIS 20

Model Enter	Unstandardized Coefficients		Standardized Coefficients	T	Sig.	95% Confidence Interval for B	
	B	Std. Error	Beta			Lower Bound	Upper Bound
R=0.035 R^2=0.001 F=0.251 df=1 p=0.617							
R=0.106 R^2=0.011 F=2.353 df=1 p=0.127							
Subjective fatigue	.176	.115	.106	1.534	.127	(.050)	.402
R=0.090 R^2=0.008 F =1.684 df=1 p=0.196							
Concetracion	.148	.114	.090	1.298	.196	(.077)	.372
R=0.091 R^2=0.008 F=1.745 df=1 p=0.188							
Motivation	.147	.111	.091	1.321	.188	(.072)	.366
R=0.119 R^2=0.014 F=2.991 df=1 p=0.085							
Productivity	.185	.107	.119	1.730	.085	(.026)	.396
R =0.117 R^2=0.014 F=2.891 df=1 p=0.091							
Total CHIS-20	.218	.128	.117	1.700	.091	(.035)	.471
R =0.068 R^2=0.005 F=0.951 df=1 p=0.329							

Dependent variable: DBQ-Aggressive violations,*significant for p<0.05

However, several fatigue domains significantly predicted ordinary traffic violations. Reduced concentration explained 4.8% of the variability in ordinary violations (R^2=0.048, p =0.001), while reduced motivation explained 5.4% (R^2=0.054, p=0.001). Reduced productivity demonstrated the strongest association, accounting for 18.9% of the variability in ordinary violations (R^2=0.189, p=0.006). Overall chronic fatigue (CIS-20 score) explained 6% of the variability in ordinary violations (R^2=0.060, p<0.001).

Table 3. Bivariate linear regression analysis of ordinary violations with selected parameters

Model Enter	Unstandardized Coefficients		Standardized Coefficients	T	Sig.	95% Confidence Interval for B	
	B	Std. Error	Beta			Lower Bound	Upper Bound
R=0,053 R^2=0,003 F=0,596 df=1 p=0,441							
Subjective fatigue	.195	.082	.163	2.383	.018*	.034	.356
R=0,192 R^2=0,037 F=7,983 df=1 p=0,005							
Concentration	.228	.081	.192	2.825	.005*	.069	.228
R=0,115 R^2=0,013 F=2,771 df=1 p=0,097							
Motivation	.133	.080	.115	1.665	.097	(.024)	.290
R=0,009 R^2=0,000 F=0,019 df=1 p=0,891							
Productivity	.011	.078	.009	.137	.891	(.142)	.164
R=0,136 R^2=0,019 F=3,925 df=1 p=0,049							
Total CHIS-20	.183	.092	.136	1.981	.049*	.001	.364
R=0.074 R^2=0.005 F=1.143 df=1 p=0.286							

Dependent variable: DBQ-Ordinary violations, *significant for p<0.05

Analysis of omissions revealed that reduced concentration significantly predicted 3.7% of the observed variability (R^2 = 0.037, p = 0.005), while overall chronic fatigue accounted for 1.9% (R^2 = 0.019, p = 0.049).

Table 4. Bivariate linear regression analysis of "Omissions" with selected parameters

Model Enter	Unstandardized Coefficients		Standardized Coefficients	T	Sig.	95% Confidence Interval for B	
	B	Std. Error	Beta			Lower Bound	Upper Bound
R=0.053 R^2=0.003 F=0.596 df=1 p=0.441							
Subjective fatigue	.195	.082	.163	2.383	.018*	.034	.356
R=0.192 R^2=0.037 F=7.983 df=1 p=0.005							
Concentration	.228	.081	.192	2.825	.005*	.069	.228
R=0.115 R^2=0.013 F=2.771 df=1 p=0.097							
Motivation	.133	.080	.115	1.665	.097	(.024)	.290
R=0.009 R^2=0.000 F=0.019 df=1 p=0.891							
Productivity	.011	.078	.009	.137	.891	(.142)	.164
R=0.136 R^2=0.019 F=3.925 df=1 p=0.049							
Total CHIS-20	.183	.092	.136	1.981	.049*	.001	.364
R=0.074 R^2=0.005 F=1.143 df=1 p=0.286							

Dependent variable: Omissions, *significant for p<0.05

No statistically significant relationship was identified between chronic fatigue and driving errors.

Table 5. Bivariate linear regression analysis of "Errors" with selected parameters

Model Enter	Unstandardized Coefficients		Standardized Coefficients	T	Sig.	95% Confidence Interval for B	
	B	Std. Error	Beta			Lower Bound	Upper Bound
R=0.029 R^2=0.001 F=0.180 df=1 p=0.672							
R=0.076 R^2=0.006 F=1.222 df=1 p=0.270							
Subjective fatigue	.068	.062	.076	1.105	.270	(.053)	.189
R=0.086 R^2=0.007 F=1.536 df=1 p=0.217							
Concentration	.076	.061	.086	1.239	.217	(.045)	.196
R=0.052 R^2=0.003 F=0.562 df=1 p=0.454							
Motivation	.045	.060	.052	.750	.454	(.073)	.162
R=0.036 R^2=0.001 F=0.272 df=1 p=0.601							
Productivity	(.030)	.058	(.036)	(.523)	.601	(.144)	.084
R=0.050 R^2=0.002 F=0.517 df=1 p=0.473							
Total CHIS-20	.050	.069	.050	.719	.473	(.087)	.186
R=0.046 R^2=0.002 F=0.432 df=1 p=0.512							

Dependent variable: OVS-Errors, *significant for p<0.05

Discussion

Fatigue is widely recognized as one of the leading human factors contributing to road traffic accidents among professional drivers. Numerous studies have indicated that 20–50% of commercial vehicle accidents occur because of fatigue[12]. Long working hours, insufficient sleep, irregular schedules and prolonged driving increase the likelihood of fatigue, impairing cognitive performance and reducing driving safety.

Fatigue is a multidimensional condition that affects alertness, attention, concentration, reaction time, motivation, and productivity[13]. In the present study, chronic fatigue was primarily manifested through reduced concentration and productivity. Although the overall level of chronic fatigue among the participants was relatively low, concentration difficulties represented the most affected domain, indicating that even mild fatigue may impair the cognitive functions required for safe driving, consistent with the findings reported by Philip and Åkerstedt[14].

Professional drivers may underestimate the severity of fatigue or continue driving despite recognizing symptoms of reduced alertness, thereby increasing the risk of unsafe driving behavior. Reduced concentration and increased mental workload were identified as major contributors to driving errors and traffic accidents[15,16].

The present study demonstrated that chronic fatigue significantly influenced several categories of unsafe driving behavior. Although no significant association was found between fatigue and aggressive violations, chronic fatigue predicted ordinary traffic violations and omissions. Drivers with poorer concentration, reduced motivation, and lower productivity reported a higher frequency of ordinary violations, while reduced concentration and overall chronic fatigue were associated with more frequent omissions. These findings are consistent with other studies indicating that fatigue contributes to unsafe driving behavior by impairing attention, vigilance, and self-regulation. Smith reported that driving while fatigued was independently associated with poor driving behavior and increased crash risk, even after adjustment for demographic, occupational and lifestyle factors. Furthermore, fatigue-related impairments in concentration and vigilance have been identified as important mechanisms underlying driving errors and unintentional omissions, supporting the associations observed in the present study[17].

Among all fatigue dimensions, reduced productivity showed the strongest association with ordinary traffic violations, explaining nearly one-fifth of their variability. Concentration was another important predictor, confirming that cognitive impairment caused by fatigue negatively affects driving performance. These findings support previous research indicating that fatigue compromises attention, information processing, and decision-making, thereby increasing the probability of unsafe driving.

Omissions, which represent unintentional failures of attention or memory, were also associated with chronic fatigue. Drivers experiencing reduced concentration were more likely to overlook traffic signs, deviate from planned routes, or fail to notice important traffic information. These findings are further supported by recent evidence from Goodwin *et al*., who demonstrated that aspects of shift work, sleep disruption, and fatigue are differentially associated with self-reported driving behaviors and collision-related outcomes. Their findings suggest that fatigue-related impairments may be more consistently reflected in measures of driving performance and attentional failures than in deliberate risky driving behaviors, which is in line with the pattern observed in the present study[18].

Unlike ordinary violations and omissions, aggressive violations and driving errors were not significantly predicted by chronic fatigue in this study. This suggests that aggressive driving behavior may be more strongly influenced by personality traits, attitudes, or situational factors than by fatigue alone.

Overall, the findings confirm that chronic fatigue mainly affects cognitive aspects of driving rather than deliberate risky behavior. Reduced concentration, motivation, and productivity contribute to poorer driving performance and increase the frequency of unintentional violations, emphasizing the importance of fatigue prevention among professional drivers.

Conclusion

Fatigue represents a significant occupational and public health issue among professional drivers and constitutes an important risk factor for unsafe motor vehicle operation. The present study demonstrated that chronic fatigue primarily affected concentration and productivity and contributed to ordinary traffic violations and omissions. Reduced concentration, motivation, and productivity were identified as significant predictors of unsafe driving behavior, while no significant association was observed between fatigue and aggressive violations or driving errors.

These findings highlight the need for comprehensive fatigue management strategies within the transport sector. Preventive measures should include improved organization of working hours, limitations on prolonged driving and shift duration, adequate rest periods, and compliance with regulations governing drivers' working time. Early identification and treatment of sleep disorders, particularly obstructive sleep apnea, should become an integral part of occupational health surveillance for professional drivers.

In addition, educational programs should be implemented to increase awareness of the risks associated with fatigue and to encourage drivers to recognize its early symptoms and adopt appropriate preventive behaviors. Employers, occupational health professionals, and transport authorities should work collaboratively to develop evidence-based fatigue management programs aimed at reducing fatigue-related crashes and improving road safety.

Conflict of interest statement. None declared.

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