

# Injured Professional Drivers in Poland— An Analysis of the Causes and Effects in Relation to the Time of the Road Accident

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**Introduction.** The objective of the paper was to present the results of an analysis of road accidents in professional drivers in Poland, from the point of view of their age, tenure, accident causes and effects in relation to the time of the accidents they were involved in. **Method.** Data were obtained from a database of the Central Statistical Office. Accidents recorded in statistical accident cards from 6 consecutive years were analysed. **Results.** The overall number of injured professional drivers generally decreased over the 6 years, except for the last year of the period when the tendency to fatal and severe accidents between 23:00 and 6:59 increased. The highest percentage of fatal and severe accidents was found between 23:00 and 6:59 and was caused by medical emergencies and unsafe behaviour. The tenure of 70.89% of the injured drivers was under 10 years. Drivers who had worked for over 20 years had fewest injuries between 23:00 and 6:59. **Conclusion.** The results of the analysis may be used in changing work schedules to reduce the accident risk of the occupational groups at greatest risk.

accidents   injury professional drivers   causes   effects   time of accidents

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## 1. INTRODUCTION

Road safety is very important these days. The rapid development of the vehicle industry in Poland has brought an increase in road casualties. They, in turn, in addition to moral and financial losses, have brought the public's justified anxiety.

According to a report of the National Road Safety Council on road safety in Poland, there were 46876 road accidents in 2006; 5243 people were killed and 59123 were injured in these accidents. Road accident statistics from 2006, based on data obtained from Polish National Police show that drivers caused 72.9% of those accidents. They were responsible for 3729 fatalities and 49784 injuries. From 1990 to 2004 the number of vehicles increased in Poland by 85%, the motorization index

increased by 127% (from 138 to 314 vehicles per 1000 inhabitants) and road transport increased by 190% [1]. Poland has one of the highest accident severity rates in Europe. According to the European Transport Safety Council, ~11 people are killed per 100 road accidents, while in many European countries this rate is only 3 per 100 [2].

Research into improving road safety by limiting the role of human factors in road accidents, conducted in a population of drivers, focuses on monotony, sustained mental stress, flexible working hours, age and drivers' psychomotor performance [3, 4, 5, 6, 7, 8]. Recently, studies of road safety have focused on the causes and the effects of driver fatigue [9]. Attempts are made to develop effective warning systems for drivers who have fallen asleep while driving. According to

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Circadian Technologies, at least 33% of drivers have experienced falling asleep while driving; this percentage increases to 80% in shift workers [10]. Falling asleep while driving, at night and at any other time of the day, caused by sleep deprivation and fatigue, is a major contributor to traffic accidents [11, 12, 13]. The effect of commonly used stimulants, such as caffeine and alcohol, on drivers' mental capacity seems crucial as well [14, 15, 16].

It is also important to know what decreases drivers' performance: physical factors (e.g., noise, vibrations, temperature) [17, 18, 19]; medical conditions (myocardial infarction, obstructive sleep apnea, diabetes mellitus, phlebothrombosis of the lower limbs) [20]; and circadian oscillations that influence drivers' capacity [10, 21, 22, 23]. This paper concentrates solely on data from reports on accidents involving professional drivers. Particular attention is focused on those parts of the reports that are related to drivers in an attempt to associate them with the time of the accidents they were involved in.

As there are no official data on the total number of professionally active drivers on the road (over 24 h, at certain times of the day or at certain times of the day and night), it was impossible to carry out occupational risk assessment. The objective of the accident analysis in the population of professional drivers was to establish whether specific hours were particularly important due to a relatively substantial role of human factors in accidents resulting in drivers' injuries.

## 2. METHOD

Accidents at work were analysed for a group of professional drivers injured in accidents during 6 consecutive years before Polish accession to the European Union. This information was obtained from the database of the Central Statistical Office, which contains information about injured drivers, the causes and results of accidents and the factors involved. Employees responsible for occupational safety and health at a given company reported all work-related accidents using a statistical accident card (SAC). The analysis comprised 30491 SAC reports on accidents resulting in injured

professional drivers. In the SAC occupational classification, the occupational code for this group of employees is 832; the code used in ISCO-88 [24].

According to the resolution of the Polish Minister of Economy and Labour on a classification of occupations for the labour market and the scope of its application [25], the term vehicle drivers refers to car, bus, tram and lorry drivers. An accident at work is defined as a sudden incident at work, which leads to physical and mental injuries, and results in death or sick leave of more than 3 days.

In our analysis, drivers injured in accidents at work were divided into groups according to the following criteria:

- age ( $\leq 29$ , 30–39, 40–49,  $\geq 50$  years old);
- tenure ( $< 10$ , 10–20,  $> 20$  years);
- result of accident (fatal or serious injury resulting in vision, hearing or speech loss, infertility, or other kind of injury or health deterioration, affecting basic functions of the human body, incurable or life-threatening diseases, terminal mental illness, complete or substantial inability to work or permanent serious deformity);
- cause of accident (in terms of human factors),
  - the driver's mental and physical condition that makes driving unsafe due to sudden illness, physical indisposition, fatigue, stress, insufficient attention while driving, a medical emergency, e.g., stroke or myocardial infarction (cause A),
  - drivers' unsafe behaviour, e.g., driving or stopping in prohibited places, driving into a dangerous area without making sure this is safe, driving too fast (cause B).

To analyse the results of this study, all injured drivers were divided into subgroups according to the year or time of the accident. Another analysis involved all drivers injured during the 6-year period. They were divided according to the year and time of the accident or the division of the day into three equally long periods: 7:00–14:59; 15:00–22:59 and 23:00–6:59. The results were statistically analysed with the  $\chi^2$  test and the fraction comparison test.

3. RESULTS

3.1. Time of Accident

Having accepted the division of the day into three periods, we can say that most accidents took place between 7:00 and 14:59 (Figure 1).

After 1997 (100%), the number of injured professional drivers clearly decreased compared to 2002 by ~30% for accidents that took place between 15:00 and 22:59 and by ~10% for those that took place between 23:00 and 6:59 (Figure 2). In 2001–2002, however, there was an

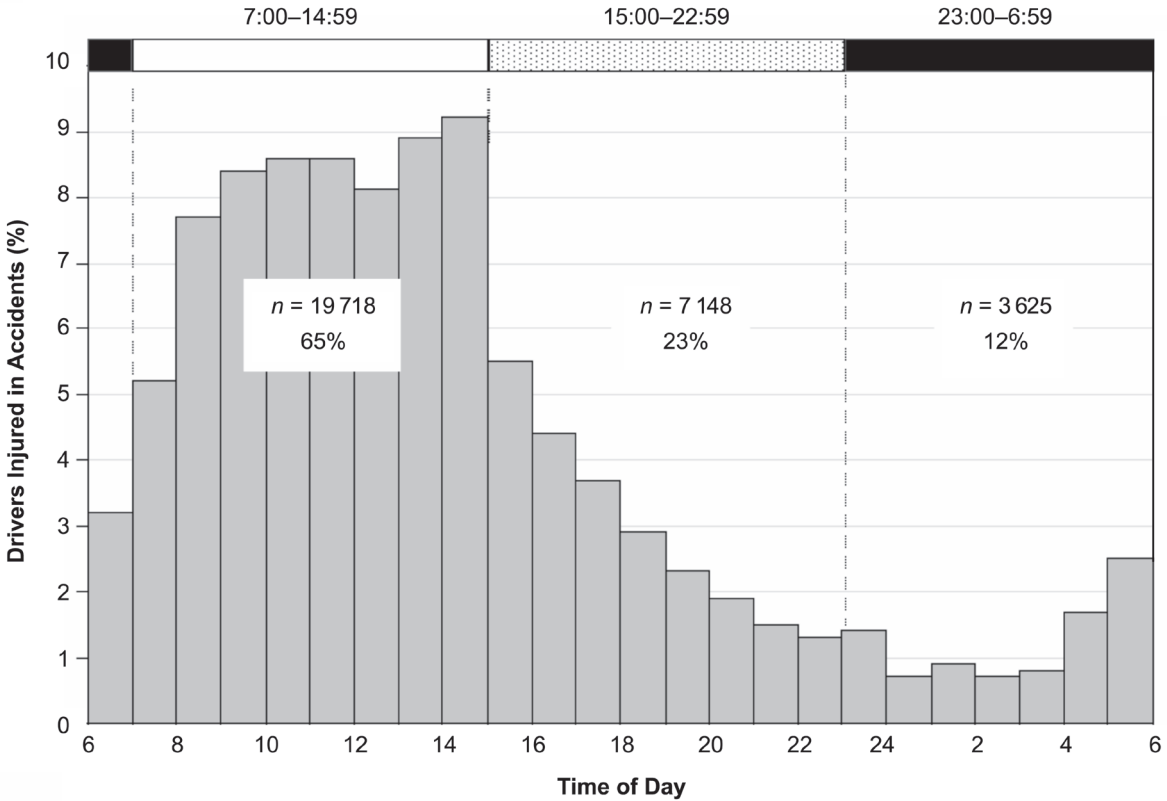


Figure 1. Drivers injured in accidents at work by time of accident (raw data from Poland’s Central Statistical Office). Notes. 100%—drivers involved in accidents at work in 1997–2002 (n = 30 491).

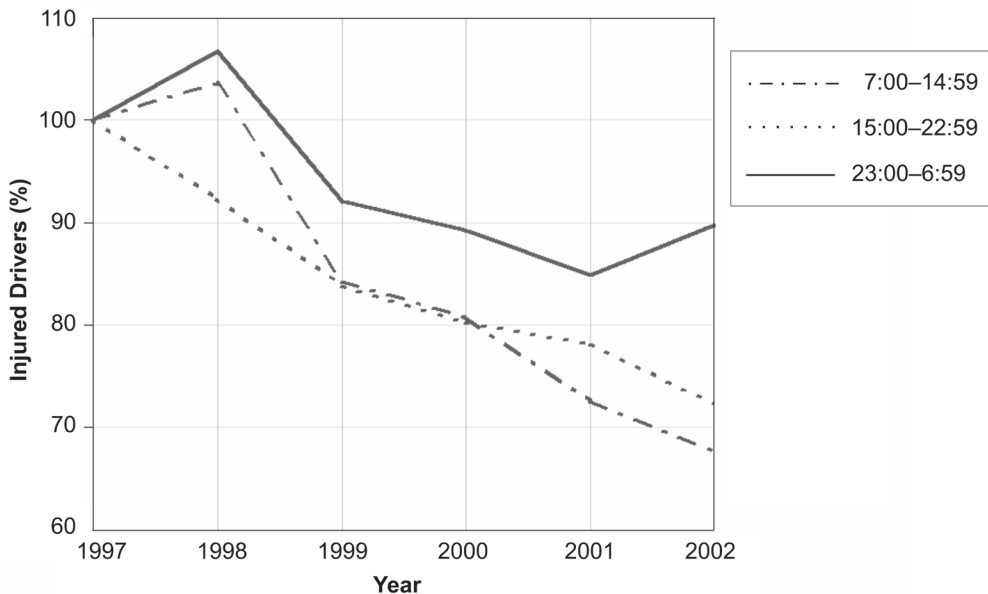


Figure 2. Professional drivers injured in accidents at work in 1997–2002 by the time of day and year (raw data from Poland’s Central Statistical Office). Notes. 100%—drivers injured at the same time in 1997.

incremental tendency in the number of drivers who sustained injuries at night (23:00–6:59).

**3.2. Age of Injured Drivers and Time of Accident**

Most professional drivers injured in accidents in 1997–2002 were 40–49 years old; fewest were 50 or over (Figure 3, Table 1). The proportion was the same for each of the three periods of the day.

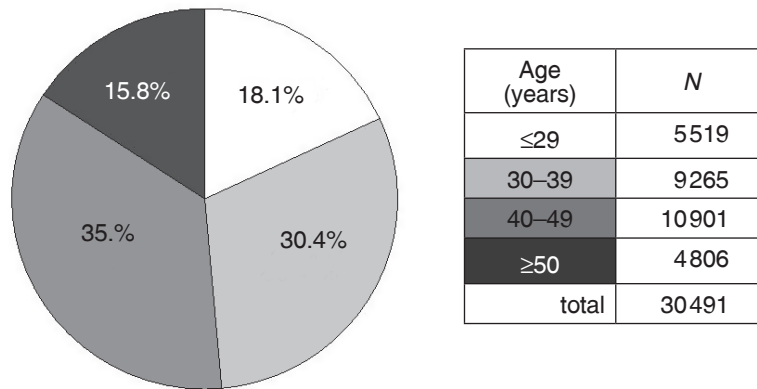
An analysis of all drivers injured in accidents by age and time of accident showed that fewer over-50 drivers had accidents at night (23:00–6:59) than during the day (7:00–14:59). Similar results were obtained in the youngest group (Table 1). An analysis of each age group’s involvement in accidents that took place at the same time of the day did not show any tendency indicating a relationship between the driver’s age and the time

of accident; these data are not presented in this article.

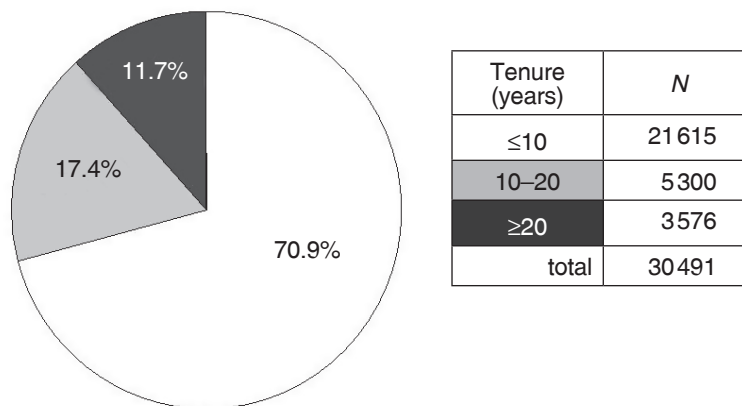
**3.3. Tenure and Time of Accident**

Tenure determines drivers’ professional experience. An analysis of 30491 professional drivers injured in accidents in 1997–2002 and their tenure showed that most injured drivers had worked for fewer than 10 years (Figure 4).

The percentage of injured drivers for the subgroups formed according to the drivers’ tenure was similar during the three periods of the day (Table 1). An analysis of the distribution of injured drivers divided according to their tenure, per 24 h, indicated that those working for over 20 years had fewest accidents between 23:00 and 6:59. A reverse phenomenon was true in injured drivers with tenure of fewer than 10 years.



**Figure 3. Distribution of professional drivers injured in accidents at work in 1997–2002 by age (raw data from Poland’s Central Statistical Office).**



**Figure 4. Distribution of professional drivers injured in accidents at work in 1997–2002 by tenure (raw data from Poland’s Central Statistical Office).**

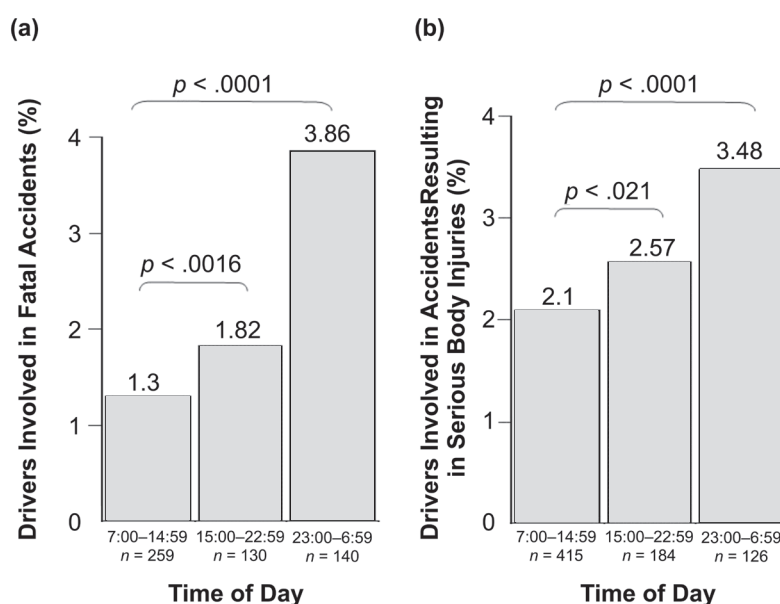
### 3.4. Fatal and Serious Accidents and Time of Accident

During the 6-year period from 1997 to 2002, 1.73% of professional drivers ( $n = 529$ ) were

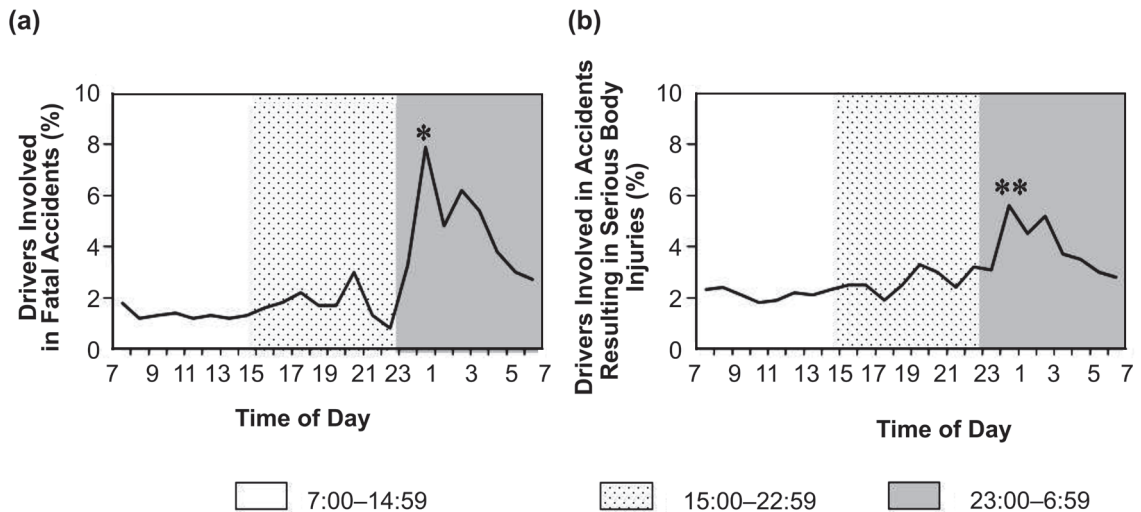
involved in fatal and 2.38% ( $n = 725$ ) in serious accidents (Figure 5, Table 1). Percentage values were also calculated for all fatalities and serious injuries, with 100% representing the total number

**TABLE 1. Drivers Injured in Accidents in 1997–2002 by Age, Tenure, Result and Cause, and Time of Accident**

Parameter		Total	%	Time of Accident					
				7:00–14:59		15:00–22:59		23:00–6:59	
				N	%	N	%	N	%
Age (years)	≤29	5519	18.10	3587	18.19	1307	18.28	625	17.24
	30–39	9265	30.40	5847	29.65	2264	31.67	1154	31.83
	40–49	10901	35.70	7102	36.02	2506	35.06	1293	35.67
	≥50	4806	15.80	3182	16.14	1071	14.98	553	15.26
	total	30491	100	19718	100	7148	100	3625	100
Tenure (years)	<10	21615	70.89	13863	70.31	5148	72.02	2604	71.83
	10–20	5300	17.38	3424	17.36	1230	17.21	646	17.82
	>20	3576	11.73	2431	12.33	770	10.77	375	10.34
	total	30491	100	19718	100	7148	100	3625	100
Result of accident	death	529	1.73	259	1.30	130	1.82	140	3.86
	serious injury	725	2.38	415	2.10	184	2.57	126	3.48
	other	29237	95.89	19044	96.60	6834	95.61	3359	92.66
	total	30491	100	19718	100	7148	100	3625	100
Cause of accident	driver's mental and physical condition made driving unsafe	22067	69.30	14150	68.06	5201	70.55	2716	73.82
	driver's unsafe behaviour	4441	13.95	2815	13.54	1078	14.62	548	14.90
	other	5332	16.75	3824	18.39	1093	14.83	815	11.28
	total	31840	100	20789	100	7372	100	3679	100



**Figure 5. Professional drivers injured in accidents by their effect: (a) fatalities, (b) serious body injuries (raw data from Poland's Central Statistical Office).** Notes. 100%—drivers injured during the same period: 7:00–14:59  $n = 19718$ ; 15:00–22:59  $n = 7148$ ; 23:00–6:59  $n = 3625$ .



**Figure 6. Distribution of professional drivers injured in accidents by their effect: (a) fatalities ( $n = 529$ ), (b) serious body injuries ( $n = 725$ ) during each hour of the day (raw data from Poland's Central Statistical Office). Notes.** 100%—drivers injured in accidents at the same time of the day; \* $p < .0108$ , \*\* $p < 0.0014$  for 23:00–23:59 compared to 17:00–17:59.

of injured drivers in each period of the day. The highest percentage of fatalities was found for 23:00–6:59; whereas between 7:00 and 14:59 this percentage was threefold lower (the fraction test showed a statistically significant difference at  $p < .0001$ ).

Statistically significant differences were also found for professional drivers with serious body injuries caused by accidents at work. The  $\chi^2$  independence test showed a statistically significant correlation between time and the outcome of the accident ( $\chi^2 = 145.7$ ;  $p < .001$ ). The result of a 2-fraction comparison test showed a statistically significant difference for the percentage of drivers injured between 7:00–14:59 and 23:00–6:59 ( $p < .0001$ ), between 7:00–14:59 and 15:00–22:59 ( $p < .0216$ ), and between 15:00–22:59 and 23:00–6:59 ( $p < .0076$ ).

The distribution of fatalities and serious injuries caused by accidents during each hour of the day was analysed; 100% represented the number of drivers injured during each individual hour (Figure 6). The highest percentage of drivers was involved in fatal accidents between 24:00 and 00:59; they constituted 7.9% of all road casualties at that time ( $n = 17$  out of 215 casualties). Two percent of professional drivers had fatal accidents between 7:00 and 19:00. The percentage of accidents between 00:00 and 00:59

was statistically different from the percentage of accidents between 23:00 and 23:59 at  $p < .0108$ .

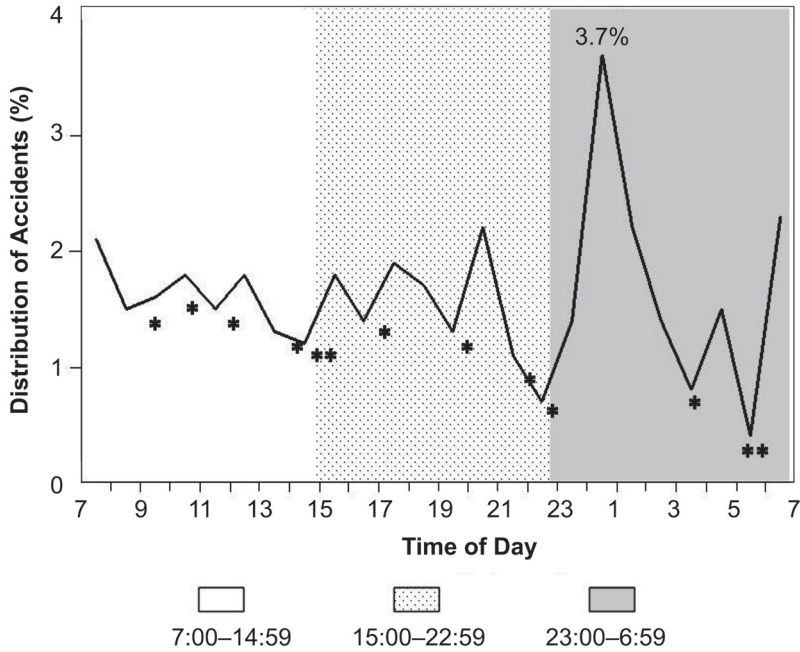
The percentage of drivers seriously injured was highest (5.6%) between 00:00 and 00:59. The difference between that percentage and the percentage of drivers seriously injured between 17:00 and 17:59 was statistically significant.

### 3.5. Mental and Physical Condition, and the Time of Accident

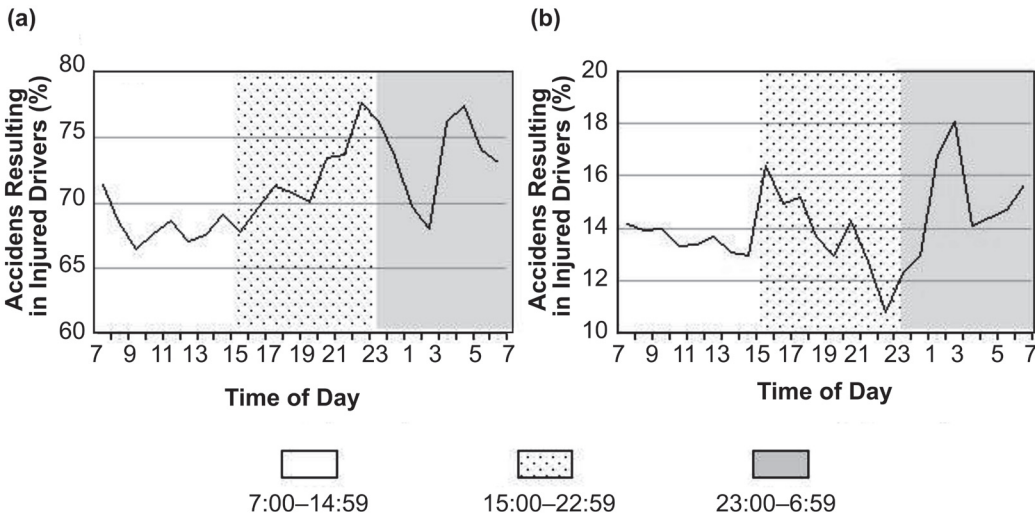
SACs contain information about the causes of accidents. The cause variable contained 31840 data, i.e., more than the number of drivers involved. That was so because in some cases an accident had several causes. The most frequent cause (69.3%;  $n = 22069$ ) was that the driver's mental and physical condition made driving unsafe (cause A).

Only two causes of accidents were determined. Both of them were medical emergencies: myocardial infarction and stroke (Figure 7). They applied to only 1.6% of professional drivers injured in accidents at work in 1997–2002. An analysis of the number of drivers involved in accidents during each hour of the day showed that most accidents caused by medical emergencies (3.7%) took place between 00:00 and 1:00. Most professional drivers were injured at 22:00 (77.6%) and 4:00 (77.3%). Their accidents were the effect of cause A (Figure 8).





**Figure 7. Distribution of professional drivers injured in accidents in 1997–2002 due to a medical emergency, e.g., stroke or myocardial infarction ( $n = 482$ ) (raw data from Poland’s Central Statistical Office). Significance of the differences was determined between a given time and part of the day. Notes. 100%—drivers injured in accidents; \* $p < .020$ , \*\* $p < .001$ .**



**Figure 8. Professional drivers injured in accidents due to (a) their mental and physical condition that made driving unsafe, (b) their unsafe behaviour (raw data from Poland’s Central Statistical Office). Notes. 100%—accidents that took place at the same time of the day.**

**3.6. Drivers’ Unsafe Behaviour and Time of Accident**

The second most frequent cause reported was the drivers’ unsafe behaviour (cause B). This cause constituted 13.9% of all of the causes in section 3.6. ( $n = 4441$ ). The remaining causes

were related to different aspects of badly planned work schedules (Figure 8). The second reported cause (cause B), drivers’ unsafe behaviour, was the most frequent cause of accidents between 1:00 and 3:00; up to 18.1% of drivers were injured at that time.

#### 4. DISCUSSION

The results presented in this paper, based on SAC data, indicate that professional drivers injured in accidents at work in 2000 were involved in ~8% of the total number of accidents that year. The assumption is that one professional driver was injured in one road accident.

Our analysis showed that road accidents which involved professional drivers were not equally frequent at all times of the day. This is obvious as most drivers use roads in daytime. Professional drivers, however, transport goods and people on long-distance routes mainly at night. Even though traffic is substantially less intensive at night, several factors make safe driving difficult: poorer visibility, greater monotony and decreased performance due to circadian rhythmicity of life processes, e.g., oculomotor co-ordination impairment, longer response time, muscle strength impairment, decrease in body temperature and heart rate, and increased sleep requirement.

Professional drivers with long tenure, who regularly drive at night, may also experience ailments usually observed in shift and night workers, i.e., diseases of the circulatory, digestive or nervous systems. They may develop those diseases earlier than day workers [26, 27]. These authors' analysis of drivers injured in road accidents found that diseases of the circulatory system constituted greater accident risk at night, around midnight (Figure 7).

For a professional driver, fatigue is a serious problem, especially at night. Fatigue is defined as a state of decreased alertness of the mind, leading to performance impairment during cognitive and psychomotor tasks including driving [13, 28, 29, 30, 31].

An analysis of accidents showed that fatigue, according to the SAC classification, was an element of the employee's mental and physical condition that made driving unsafe (cause A). This cause was most frequently true for injured drivers, who had accidents between 23:00 and 6:59 (73.82%). The contribution of fatigue during individual hours was highest between 22:00 and 24:00, and between 3:00 and 5:00 (Figure 8).

Falling asleep at the wheel is a possible cause of accidents. Few researchers have undertaken studies linking the frequency of accidents with the time of day. Among numerous scientific reports on industrial accidents, only a few, on shiftwork, have attempted to link accidents and time [13, 32, 33, 34, 35].

An analysis of all road accidents in Poland in 2000, based on the data obtained from Polish National Police, showed that most accidents occurred between 16:00 and 19:00, with a peak between 17:00 and 18:00, i.e., during very heavy commuting traffic. Most people were injured between 16:00 and 19:00, and killed between 17:00 and 21:00. All road users were casualties, not only drivers [1]. Our analysis of professional drivers injured in road accidents only did not find such a distribution of casualties for each hour of the day. The highest percentage of fatalities and seriously injured drivers was found for 23:00–6:59.

Fewer drivers over 50 years old were injured in accidents between 23:00 and 6:59 than during the other parts of the day. Possibly, drivers over 50 did not easily agree to drive at night due to associated circadian rhythmicity disorders observed in other shift workers (including sleep disruption and risk of short doses), and preferred working between 7:00 and 22:59. It is also possible that older drivers were generally involved in fewer accidents because of greater work experience. However, this was difficult to confirm because professional drivers working at a given time of day were not divided into age groups.

An analysis of the rate of accidents at work and workers' age should show older workers' more frequently age-related decrease in mental performance. In their studies of injuries among steel industry workers, Ogiński et al. found that the age structure of accident victims did not differ from the age structure of all workers of the plant, which means that older people are not more prone to accidents [33]. A cumulative analysis of the time of accident and the workers' age showed that younger workers were involved in almost 40% of accidents during their night shift, while in the older group, only 28% of accidents happened



at night. According to Ogiński et al. a better strategy of safety measures taken at night, i.e., time believed to be particularly dangerous, and the so-called natural selection among workers explained this fact [33]. According to Tay, too, an increase in the number of licenses issued to ageing drivers did not have a significant impact on the number of fatal crashes on the roads [36].

An analysis of the time of accident made it possible to determine the time, over 24 h, when most professional drivers had accidents. Lack of information about the number of professional drivers working in 1997–2002, and the number of drivers on the road during each hour of the day, makes a correct evaluation of accident risk impossible. It is only possible to make an evaluation on the basis of information about traffic intensity, related to all vehicle movement.

The decline in the number of professional drivers injured in accidents in 1997–2002 is a positive phenomenon especially that at the same time road transport and the number of vehicles increased greatly in Poland. An improvement in the standard of roads, better road signs and an improvement in road users' (both drivers' and pedestrians') behaviour can all explain this fact. It seems strange, however, that the number of drivers injured at night does not decrease to the same degree as during daytime. The analysis of injured drivers presented in this paper suggests that human factors are more likely to contribute to accidents at night than during the day. The cumulative analysis of accidents and the time of their occurrence may suggest the necessity to adapt accident prevention methods to the time of day, especially to reduce the number of accidents related to human factors.

When training professional drivers, more attention should be paid to the role of human factors and their aspects in reducing the number of accidents. Moreover, human factors related to driving at various times over 24 h should be focused on.

## 5. CONCLUSIONS

Between 1997 and 2002 Poland experienced a tendency to a decrease in the percentage of professional drivers injured in accidents at work. The increase in the number of drivers injured between 23:00 and 0:59 in 2001–2002 was an exception.

Most drivers were injured in accidents at work that took place between 7:00 and 14:59 and fewest between 23:00 and 0:59. However, probably more drivers worked during the day than at night. Otherwise, most fatalities and serious accidents at work took place between 23:00 and 0:59. It is also between 23:00 and 0:59 that most accidents were caused by the mental and physical condition that made driving unsafe (cause A).

Most injured professional drivers were 40–49, independently of the time of day. This does not mean, however, that accident risk in this group was higher than in the other ones. There is no information on the age of all professional drivers working at a given time of day. Most injured drivers, though, had shortest tenure, i.e., they had worked for fewer than 10 years.

The prevailing cause of road accidents in professional drivers was cause A, related to their mental and physical condition.

All of the conclusions in this section show that it is not enough for drivers to master driving skills. It is also necessary for professional drivers to learn that safe driving depends on their psychophysical well-being, especially at night.

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