An overview of injured bicyclists in traffic accidents: analysis of traffic accident database in Latvia for the period 2010–2014

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Abstract The Latvian national road accident statistics show that the situation is now critical for vulnerable road users', who are involved in half of injury accidents that occur on the roads, with cyclists making up the second largest category. In this paper, cyclist injuries have been analysed from the road safety accident database in Latvia for the years 2010–2014. The annual rate of injured cyclists increased from 344 injured cyclists in 2010 to 527 in 2014. Only 22.7% of cyclists were involved in accidents during twilight or darkness, but at the same time the fatality rate was higher during this times. Out of all injured cyclists, 54.5% were younger than 35 years, although the fatality rate was higher for those cyclists aged 55 years and older. Of the total number of cyclist accidents, 48.2% occurred in summer, between June and August, 22.7% occurred on a wet road surface, and 35.2% occurred during overcast, fog or rain weather conditions. Out of 75 fatalities, 70.6% involved at least one other vehicle, while one cyclist died in collision with a pedestrian. Cyclist injury risk was associated with demographical, traffic-related, visibility and road infrastructure factors.

Keywords Bicycle injury, cyclist, injury accident, road safety, vulnerable road user.

I. INTRODUCTION

The issue of cycling safety has been receiving increasing attention from researchers and from transport planners. The World Health Organization (WHO) has estimated the number of deaths on the road at over 1.2 million by combining the data of 128 countries. Road infrastructure is mainly constructed with the needs of motorists in mind, although almost half of all road traffic deaths occur among vulnerable road users, i.e. pedestrians, cyclists and motorcyclists [1]. Although a considerable decrease by 32% in the total number of bicycle fatalities in noted within the decade 2004-2013, it is still smaller than the respective reduction of the overall road fatalities by 45%. In total, cyclists make up 8% of road deaths in the European Union (EU). Within this statistic, cyclists younger than 25 years make up around one-tenth of all cyclist road deaths, with 42% of cyclist fatalities aged 65 years or older. The overall long-term trend in the EU is that the number of road fatalities is decreasing, but at the same time Latvia has reported the highest rate among member states – 105 dead per million people [2].

Thanks to the positive effects of various promotions and campaigns, people choose to cycle because it is an enjoyable physical activity that improves health and also reduces road congestion and environmental pollution [3]. It is also relatively inexpensive, makes for convenient parking and is the fastest mode of transport for short distances in urban areas. Cycling is accessible to most of the population and easy to incorporate into daily life [4], but the downside is that it also brings the risk of serious injury, and even death. Addressing this issue demands careful transport planning, investment in infrastructure and strengthening of safety law. Since 2014, there is a national bicycle helmet law for children up to 12 years in Latvia [2]. At the same time, vulnerable road users are one of the top priorities defined in the national road safety program. The road safety plan proposes improvement of laws and regulations, improved road user behaviour control and improved road users' awareness [5]. This is welcome and necessary given that cycling is becoming more and more popular in Latvia.

This study analyses road traffic bicycle injuries and the relationship between injuries and the circumstances in which they occur: injury typology; severity; and causation, such as demographic characteristics and crash circumstances, including weather conditions and road typology.

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II. METHODS

In this study, only road traffic accidents with injured bicyclists are analysed. The current study used the statistical database of road safety accidents and consequences in Latvia for the years 2010 to 2014, which database is held by Road Traffic Safety Directorate, under the Ministry of Transport of Latvia. The information held on the database covers close to 100% of all cases reported to the traffic police. Data are collected from administrative protocols, which includes protocols following road traffic accidents and fine receipts from road police and protocols and reports from other institutions for road traffic offenses (for example, information on road traffic accidents without casualties is obtained from vehicle insurers).

Data-gathering protocol was followed for each case, then on-site investigation was carried out in order to identify pre-crash phenomena, such as road layout, light and weather conditions.

According to Road Traffic Safety Directorate as "death" are considered those, who have died in the accident site or within 30 days after that. "Severe injuries" are those who are hospitalized for more than one day, "minor injuries" - for those hospitalized for up to 24 hours.

For all injured cyclists, the following information was collected and analysed:

- cyclist-related variables: age (younger than 35, 35–54, 55 and older), sex and severity of injuries (death, severe or minor injuries);
- environmental variables: zone (open road, urban), time (daylight, twilight, darkness), type of day (working day or weekend), month of the year, surface and overcast weather conditions;
- BAC (blood alcohol concentration) prior to the accident.

Data were downloaded, processed and analysed using descriptive statistics, Pearson's chi-squared and calculations of statistical reliability with SPSS for Windows 20.0. The 95% confidence interval (CI) was used to estimate the precision of the odds ratio (OR).

III. RESULTS

From 2010 to 2014, 2,177 cyclists were injured in reported road traffic accidents in Latvia. Injury accident risk for injured cyclists comparing to all injury accidents has increased. The annual rate of injured bicyclists is displayed in Table I.

TABLE I
annual number by severity and proportion of injured bicyclists

Year	Minor injuries	Serious injuries	Fatalities	Total number (% of cases in period)	Proportion of injured cyclists among all injury accidents	Odds to get injury in bicycle crashes (95% CI)
2010	292 (84.9%)	39 (11.3%)	13 (3.8%)	344 (15.8%)	8.1%	0.831 (0.739-0.937)
2011	367 (84.4%)	53 (12.2%)	15 (3.4%)	435 (20.0%)	9.9%	1.013 (0.910-1.129)
2012	364 (86.9%)	37 (8.8%)	18 (4.3%)	419 (19.3%)	9.6%	0.986 (0.884-1.008)
2013	394 (87.2%)	45 (10.0%)	13 (2.9%)	452 (20.8%)	10.0%	1.026 (0.923-1.141)
2014	477 (90.5%)	34 (6.5%)	16 (3.0%)	527 (24.2%)	10.9%	1.112 (1.015-1.240)

Cyclist characteristics

There were 1,338 males (61.5%) and 482 females (22.1%) among injured cyclists; in 16.4% of accidents sex was not recorded in the police protocol. Most of injured cyclists (54.5%) were under 35 years old, but the fatality rate was higher for those 55 years and older. The characteristics of injured cyclists according age are displayed in Table II. Differences between sex and injury/fatality rate (Pearson's chi-squared test χ^2=7.196; p-value<0.027) are statistically significant. Differences between age groups and injury/fatality rate (Pearson's chi-squared test χ^2=32.544; p-value<0.0001) are statistically significant.

TABLE II
THE NUMBER AND PROPORTION BY AGE AND SEVERITY IN STUDY PERIOD

Age	Minor injuries	Serious injuries	Fatalities	Total number (%) of all cases by age groups
Younger than 35	1,080 (91.0%)	88 (7.4 %)	19 (1.6 %)	1,187 (54.5%)
35–54	452 (85.4%)	54 (10.2%)	23 (4.3%)	529 (24.3%)
55 and older	362 (78.5%)	66 (14.3%)	33 (7.2%)	461 (21.2%)
Total number (%) of injury by severity in all ages	1,894 (87.0%)	208 (9.6%)	75 (3.4%)	2,177 (100%)

Accident type

There were 1,539 (70.7%) injured cyclists in accidents with motor vehicle involved, 599 (27.5%) in bicycle accident and 39 (1.8%) collisions with a pedestrian. There were 63 (4.1%) fatalities (person died in the accident site or within 30 days after the accident), with motor vehicle involved. One cyclist died in a road traffic accident with a pedestrian. The characteristics of injured cyclists according accident type are displayed in Table III.

TABLE III
CHARACTERISTICS OF INJURED BICYCLISTS ACCORDING TO ACCIDENT TYPE AND SEVERITY

Accident type	Minor injuries	Serious injuries	Fatalities	Total number (%) of all cases by accident type
Accidents with one or more motor vehicles involved	1,334 (86.7%)	142 (9.2%)	63 (4.1%)	1,539 (70.7%)
One vehicle accidents	524 (87.5%)	64 (10.7%)	11 (1.8%)	599 (27.5%)
Accidents with a pedestrian	36 (92.3%)	2 (5.1%)	1 (2.6%)	39 (1.8%)
Total number (%) of all cases by severity	1,894 (87%)	208 (9.6%)	75 (3.4%)	2,177 (100%)

Characteristics of accident condition

For 43.9% of injured cyclists, their accident occurred in the capital city, Riga, with 33% occurring in other big cities and 21.0% occurring on roads (main roads, regional and local roads). A total of 22.8% of injured cyclists suffered in road accidents during twilight or dark, 19.3% occurred on wet, damaged or treated road surfaces, and 46.1% occurred during overcast, fog and rain or snow weather conditions. The light, road and weather conditions are shown in Table IV. Police protocols on accident conditions were reported incomplete, which means there were missing data on light, road and weather conditions in the total numbers. Differences between light condition and injury/fatality rate (Pearson's chi-squared test χ^2=11.180; p-value<0.001) are statistically significant, fatality rate is higher for twilight and dark light conditions (odd ratio OR=2.212; confidence interval CI 1.374-3.562). Differences between road condition and injury/fatality rate (Pearson's chi-squared test χ^2=4.360; p-value<0.03) are statistically significant, fatality rate is higher for wet, damaged and treated road (OR=1.733; CI 1.028-2.921). Differences between weather condition and injury/fatality rate (Pearson's chi-squared test χ^2=15.032; p-value<0.0001) are statistically significant, fatality rate is higher for adverse weather (OR=2.567; CI 1.568-4.201).

TABLE IV
CHARACTERISTICS OF INJURED BICYCLISTS ACCORDING TO LIGHT, ROAD AND WEATHER CONDITIONS AND SEVERITY

		Minor or serious injuries	Fatality	Total number(%) of all cases by accident condition
Light condition	Daylight	1,572 (97.2%)	46 (2.8%)	1,618 (77.2%)
	Twilight, dark	448 (93.9%)	29 (6.1%)	477 (22.8%)
	Total number (%) of injury by severity	2,020 (96.4%))	75 (3.6%)	2,095 (100%)
Road condition	Dry road surface	1,296 (96.1%)	52 (3.9%)	1,348 (80.7%)
	Wet, damaged or treated road surface	302 (93.5%)	21 (6.5%)	323 (19.3%)
	Total number (%) of injury by severity	1,598 (95.6%)	73 (4.4%)	1,671 (100%)
Weather condition	Not adverse weather	1,105 (98.0%)	24 (2.0%)	1,174 (53.9%)
	Adverse weather (overcast, fog, rain or snow)	952 (94.5%)	51 (5.0%)	1003 (46.1%)
	Total number (%) of injury by severity	2,102 (96.6%)	75 (3.4%)	2,177 (100%)

Season and weekday characteristics

Over the years studied, 48.2% of injured cyclists suffered accidents during the summer months (June, July and August), 20.5% in the spring (March, April and May) and 26.3% in the autumn (September, October and November). Winter (December, January and February) produced the least number of bicycle injuries (5.1%) as there are obvious less bicycle riders on the street in winter compared to other seasons. Comparing the injury severity across the seasons shows that fatalities percentage in winter was higher than the others. Differences between season and injury/fatality rate are statistically significant (Pearson's chi-squared test χ^2=12.737; p-value<0.005). Characteristics of injured bicyclists according to the seasons are shown in Table V.

TABLE V
CHARACTERISTICS OF INJURED BICYCLISTS ACCORDING TO SEASONS AND SEVERITY

Season	Minor or serious injuries	Fatality	Total number (%) of all cases by season	Odds to get injury in bicycle crashes (95% CI)
Winter	100 (90.9%)	10 (9.1%)	110 (5.1%)	3.1 (1.5-6.2)
Spring	430 (96.6%)	15 (3.4%)	445 (20.5%)	0.9 (0.5-1.7)
Summer	1022 (97.3%)	28 (2.7%)	1,049 (48.2%)	0.6 (0.4-1.0)
Autumn	550 (96.2%)	22 (3.8%)	571 (26.3%)	1.7 (0.7-1.9)

Table VI presents the overall percentages of cyclist injuries by day of week. There were four times more bicycle riders with injuries on weekdays than on weekend days, but rates for fatality and serious injury were higher on weekend days than on weekdays. The analysis of injuries based on weekdays and weekend days shows statistically significant differences (Pearson's chi-squared test χ^2=39,485; p-value<0.005). Fatality rate is higher for weekends (OR=2.2; CI 1.386-3.641).

TABLE VI
CHARACTERISTICS OF INJURED BICYCLISTS ACCORDING TO DAY OF THE WEEK

Weekday	Minor injuries	Serious injuries	Fatality	Proportion of accidents by day
Monday	283 (91.0%)	21 (6.8%)	7 (2.3%)	311 (14.3%)
Tuesday	332 (89.7%)	25 (6.8%)	13 (3.5%)	370 (17.0%)
Wednesday	322 (89.7%)	31 (8.6%)	6 (1.7%)	359 (16.5%)
Thursday	307 (88.5%)	29 (8.4%)	11 (3.2%)	347 (15.9%)
Friday	310 (87.6%)	33 (9.3%)	11 (3.1%)	354 (16.3%)
Saturday	175 (78.1%)	35 (15.6%)	14 (6.2%)	224 (10.3%)
Sunday	165 (77.8%)	34 (16.0%)	13 (6.1%)	212 (9.7%)
Total	1,894 (100%)	208 (100%)	75 (100%)	2,177 (100%)
Weekdays	1,554 (89.3%)	139 (8.0%)	48 (2.8%)	1,741 (80.0%)
Weekend	340 (78.0%)	69 (15.8%)	27 (6.2%)	436 (20.0%)

BAC

During the five years under study, 239 (11.0%) injured cyclists were found to have alcohol in their blood just after the road traffic accident. Fatality rate is higher for those with exceeded BAC (OR=1.4; CI 0.7-2.7). Table VII shows overall tendencies in bicycle injuries and BAC.

TABLE VII
BAC AMONG INJURED CYCLISTS

Alcohol presence	Minor injuries	Serious injuries	Fatality	Total number (%) of all cases by BAC
No alcohol	1,697 (87.6%)	177 (9.1%)	64 (3.3%)	1,938 (89.0%)
Drunk cycling	197 (82.4%)	31 (13.0%)	11 (4.6%)	239 (11.0%)

IV. DISCUSSION

Through the analysis of traffic police data, this study systematically examined the causes of traffic injuries among cyclists in Latvia. In the period 2010–2014, data for 2,177 injured cyclists were recorded. There has been decrease in bicycle fatality rates over a five year period however Latvia still have higher cyclist fatality rate that the European Union average.

Accidents where cyclists are fatally injured mostly involved collision with a motor vehicle, and these findings correspond well with other reports on cycling. It is well established in other researches that injuries arising from crashes involving motor vehicle are most severe compared with other cycle injuries [6-8]. The number of collisions between cyclists and motor vehicle resulting in death, indicates that consideration should be given to protecting cyclists from motor vehicles.

Both injuries and fatalities in road bicycle accidents were associated with being male, which is relevant to other findings [9]. Males have a higher risk of being killed for all modes of transport. That can be explained by behaviours, when man take more risks [10-11]. The proportion of fatalities for bicyclists increases for the age group 35–44 as compared to those under 35 years old, although this increases even more for the group aged above 55 years. For comparison, Kim *et al.* [12] showed the fatality percentage to be elevated above the age of 55, while Stone and Broughton [13] showed the same after the age of 40. The increased fatality rate can be explained by physical vulnerability. Older people have a higher fatality once injured because of their frailty, as bicyclists are more vulnerable as road users because they may be more severely injured.

The role of light condition is important since results from the study show that twilight and darkness are associated with fatalities in road bicycle accidents. These results are in line with the findings of other research studies [12-13] on less visible cyclists in the dark, which can lead to collisions between cyclists and other road users. Adverse weather conditions (overcast, fog, rain or snow) were significantly associated with fatal injuries in an accident scenario. This study shows that wet, damaged or treated road surfaces are associated with cyclist fatalities. In these cases, use of reflective materials on the bike or bicyclist could likely reduce fatality risk from bicycling in dark conditions. Thus the results support the use of specifically designed bicycle paths to reduce

bicycle accident.

The analysis of the injuries showed that the greatest number occurred in accidents in the summer months, which is obvious because there are more bicycle riders on the street in summer compared to other seasons. However, the largest number of fatalities occurred in winter, a result shared with the findings of other researchers [14].

The current study also shows the relationship between fatalities and bicyclist intoxication, showing that drunk cycling is associated with injuries in bicycle accidents. Penalties for exceeding legal BAC limits for car and bicycle users differ in Latvia. It is illegal to drive a car with a BAC level exceeding 0.05%, with the punishment for exceeding that level being loss of driving license and a fine. It is also illegal to drive a bicycle with a BAC level exceeding 0.05%, but the penalty for bicycle users contravening this law is a fine only. This probably makes cyclists feel more free to drink and cycle because the penalty is relatively mild. While it is the case that driving a car drunk poses greater danger to fellow road users, it is also true to say that a drunk bicyclist could pose a great threat to his own health and wellbeing.

Reasonable and sustainable transport measures should be taken into consideration in order to increase the safety of bicycle riding [15]. As of 2016, new road traffic regulations come into force that pay particular attention to vulnerable road users. They include more established permitted bicycle traffic locations, the confining of bicycle riding to bicycle lanes or to infrastructure appropriate for cyclists, riding along the carriageway is allowed only when infrastructure is not adequate, and cyclists have to choose a speed that does not endanger or interfere with pedestrians, etc. These measures are welcome and it is hoped they will have a positive effect on the number of accidents involving cyclists.

V. CONCLUSIONS

Cyclist injuries are associated with demographical factors and accident circumstances. Nevertheless, the high frequency of non-serious injuries and the proportion of fatal cyclist injuries in road traffic crash casualties indicate the need for preventive action. To this end, injuries and fatalities may be further prevented by physical separation of cyclists and motor vehicles in urban places. With an ever growing number of cyclists, the results of the research are valuable for considerations as to how to improve road safety, including social and traffic-related factors. It is clear that both environmental and behavioral measures (targeting cyclists and drivers) aimed at reducing collisions will be important in reducing the overall incidence of cycling injuries.

This study has some limitations. Protocols on accident conditions were reported incomplete, which means there were missing data in the total numbers. At the same time the data about injured bicyclists have not been analysed in Latvia in this spin till now. The results of the analyses allow for an overall assessment of the bicycle safety level in Latvia, providing thus useful support to decision makers working for the improvement of road safety in Latvia. Certainly, the effort of data collection is an ongoing challenge and he analysis presented in this study in the future could be combined with more detailed analysis using additional data to emphasize the problem of the cyclists' road safety.

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