ANALYSIS OF COVID RESTRICTIONS' INFLUENCE ON ROAD TRAFFIC CRASHES AND RELATED ROAD USERS' BEHAVIOUR IN THE CZECH REPUBLIC

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Abstract:

The Covid pandemic and following restrictions worldwide influence various aspects -lockdown does not only have economic consequences but is also associated with a change in population mobility. As well as the spread of a pandemic and the associated numbers of infections and deaths, policy responses and restrictions have also varied from country to country. Despite all the negative impacts of the Covid pandemic, the decrease in crash-related injuries may be seen as one of the positive impacts of lockdown politics. The change in crash characteristics during the Covid lockdown may provide new insights and help design countermeasures for road safety improvement. It is not sufficient to generalize findings across individual countries, there were different trends in crash frequency and severity during the Covid lockdown The main purpose of this study was to investigate the Covid restriction's impact on road safety in the Czech Republic. The retrospective analysis was performed using data the Police crash statistics. In addition to data from the main Covid periods (2020 and 5 months of 2021 data), crash data from 2016-2019 as the period unaffected by the Covid pandemic, were used as a control group. The study focused not only on the overall crash frequency but also on the analysis of the crash frequency according to the individual crash participants. Crash data did not indicate significant changes in risky behaviour. The mobility decrease was associated with decreased crash frequency, especially of vehicles and pedestrians. The crash numbers also reflect changes in how people spend time, respectively an increase in leisure time activities in some age groups and a change in usage of transport modes. Two-wheeled vehicle users (cyclists, motorcyclists) crash frequency was more influenced by seasonality. While the crash frequency of vehicles (personal vehicles and HGVs) and pedestrians was better correlated with mobility data, the cyclists and motorcyclists crash frequency were better correlated with temperature.

Keywords: Covid, crash, behaviour, road users, pandemic, mobility

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1. Introduction

Since 2020, the world has been influenced by the Covid pandemic and following restrictions. Most governments imposed some form of lockdown to reduce public interactions and prevent the virus spread. In most countries, the countermeasures included school closures and a shift to distance learning, retail closure and home-office work where possible. As well as the spread of a pandemic and the associated numbers of infections and deaths, policy responses and restrictions have also varied from country to country. Especially in the Czech Republic, the pandemic's spread was critical.

Lockdown does not only have economic consequences but it is also associated with a change in population mobility. Mobility reduction may be also reflected in changes in crash frequency and/or severity. The crash frequency reduction, as one of the few positive factors of the Covid pandemic, has become a frequent topic in recently published papers. The paper aims to analyse the road safety impacts of a pandemic on the national level based on Czech Traffic Police crash data. Understanding of factors behind crash reduction may lead to the design of effective countermeasures for the reduction of road trauma.

The paper is structured as follows: section 2 provides a Literature review, followed by Data and methods (section 3), Results (section 4) and a final section 5 with Discussion and conclusions.

2. Literature review

The reviewed studies show different trends in crash frequencies during the Covid lockdown. While several countries showed decrease in vehicle traffic (e.g., Cui, 2020; Calderon-Anyosa et al., 2020; Katrakazas et al., 2020; Lin et al., 2021; Hughes et al., 2020; Warren, 2020; Goolsbee, 2021) and related decrease in crash frequency due to Covid pandemic (e.g., Alhajyaseen et al., 2022, Doucette, 2020; Saladie et al., 2020; Qureshi et al.; 2020; Lin et al., 2021; Hughes et al., 2020, Oguzoglu, 2020; Vandoros, 2022), several studies also highlighted an increase in crash severity (e.g., Alhajyaseen et al., 2022; Adanu, 2021; Doucette, 2020; Saladie et al., 2020; Qureshi et al., 2020; Hughes et al., 2020; Meyer, 2020).

The increase in crash severity was explained differently by authors: Brodeur (2020) considered an increase in severity due to distributional changes to traffic times; others noted lower traffic congestion and higher highway speed (Hughes et al., 2020) and an increase in speeding-related collisions (Vingilis, 2020). Tucker and Marsh (2021) pointed out that lower traffic volume may reduce drivers' ability to perceive and control their speed. Ansari (2022) warned that the disease reduces drivers' situational awareness and vigilance. Some of the previous studies described that reduced mobility was connected with risk factors such as speeding, careless driving, aggressiveness and related factors such as more frequent harsh acceleration and braking, alcohol consumption, and inattentiveness (Patwary et al., 2023, Mokhtarimousavi, 2022; Katrakazas et al., 2020; Michelaraki, 2022; Meyer, 2020; Vandoros, 2022; Vingilis, 2020; Dong, 2022; Lopetrone and Biondi, 2022). In some countries, the pandemic was also connected to increased alcohol sales and use (e.g., Barbosa, 2021; Gonçalves, 2020). Young males with restricted licences were the more likely group of drivers to drink and drive during restrictions (Watson-Brown, 2021). Stavrinos et al. (2020) suggested that older, employed, minority teens are less likely to reduce driving behaviour. Another factor related to risky behaviour during driving could be stress: e.g., Egozi et al. (2021) described the increased stress of couriers due to Covid. Quereshi et al. (2020) recommended more studies as necessary to identify reasons for the lack of reduction in serious or fatal injuries.

Vingilis et al. (2020) focused on the definition of research questions which should be considered as potential influences on traffic safety. The countermeasures could be reflected in an increase in risky behaviour – greater opportunities for speeding, and an increase in drug and alcohol consumption. Factors associated with mental health issues during the Covid pandemic situation such as stress, anxiety, depression and other psychological symptoms could be also predictors of risky and aggressive driving behaviour. Vanlaar et al. (2021) highlighted that during the pandemic, targeted enforcement strategies should be focused on risky behaviour such as speeding and impaired driving. The analysed results also indicate that the sex differences usually observed in risk-taking were not significant during the pandemic.

The change could be also seen in the usage of transport modes. Eisennmann et al. (2021) focused on changes in mobility and attitudes towards

transport modes. The results showed an increase in the use of individual modes of transport, especially private vehicles and a decrease in public transport use. The decrease could be related to the fear of the disease spread. According to the drivers in Cracow (Poland), passengers often quite freely approached the limits of people in vehicles and often did not respect social distancing, especially when alighting and boarding (Bauer et al., 2021). Sutherland (2020) recommended the development of a more robust public transport system as a long-term solution which may reduce mobility and crash-related injuries.

Vingilis (2020) highlighted the necessity to understand how the pandemic situation affects mobility, crashes, road users' behaviour and other road safety indicators, especially because it could provide new insights into the definition of factors which have a positive impact on road safety. Considering differences in the world pandemic spread and different approaches to countermeasures in each state, it seems useful to analyse the impact of the pandemic on traffic and crashes in the Czech Republic. In the Czech Republic, two main pandemic waves were defined by the state of emergency and associated with several restrictions, including lockdown, preferred home-office regime, shop closure, distance learning and travel limitations.

The motivation for the analysis of national crash data is the lack of information about driver behaviour and potential changes during the lockdown in the Czech Republic. While most of the previous studies focused on general crash frequency and severity changes, the presented study will also analyse crash frequency changes related to specific road users. To analyse whether crash characteristics changes were influenced more by mobility decrease or seasonality, the crash frequency of defined road user types was analysed in relation to mobility data and temperature.

3. Data and methods

The retrospective analysis was performed using data gathered by Czech Traffic Police. According to Czech legislation, only crashes with personal injury or property damage exceeding 100,000 Czech crowns (approx. 3800 EUR) or damage caused to a third party, are reported. In addition to data from the main Covid periods (2020 and 5 months of 2021

data), crash data from 2016-2019, i.e., the period unaffected by the Covid pandemic, were used as a control group. Weekly 2020 and 2021 data were compared to averages from 2016-2019.

Analysis was conducted in the following steps:

1. Analysis of crash frequency (overall crash frequency for all types of crashes and each participant group: cyclists, motorcyclists, personal vehicles, heavy goods vehicles, pedestrians, public transportation),

2. Analysis of crash severity (overall crash frequency for all types of crashes, and each participant group: cyclists, motorcyclists, personal vehicles, heavy goods vehicles, pedestrians, public transportation).

Additionally, domestic (Czech) vs foreign (non-Czech) drivers were considered. Moreover, correlation and linear regression were used to determine statistical associations between the crash frequency and mobility or weather conditions.

Google mobility data were retrieved from mobile phones of users who have opted-in to the "Location History" in their Google Account. Data are aggregated and anonymized and show how visits and distances to different places (grocery/pharmacy, parks, transit stations, retail/recreation, residential, and workplaces) vary in each geographic region, the accuracy varies from region to region (Google LLC, 2020). Mobility in the place of residence and parks was not considered in the comparisons, since it displayed different trends in comparison with other mobility types, probably reflecting the leisure (i.e., non-transport) activities (see Fig. 1). In addition, parks are not part of public roadways, so they are not included in the crash database.

Percentage differences were analysed not only throughout the whole covid pandemic period in 2020 and 2021 but also in individual waves of the pandemic for selected aspects.

Since there were differences in the Covid spread and following restrictions in the two analysed waves, it was not possible to define identical points for comparison. Due to the restrictions diversity during the first and second waves, waves were marked by closing/opening of retail *(in the graphs marked by red lines, by orange lines were marked the restriction of travel out of the region)*, not a state of emergency which was not terminated at the end of the year even though markets were opened before Christmas.
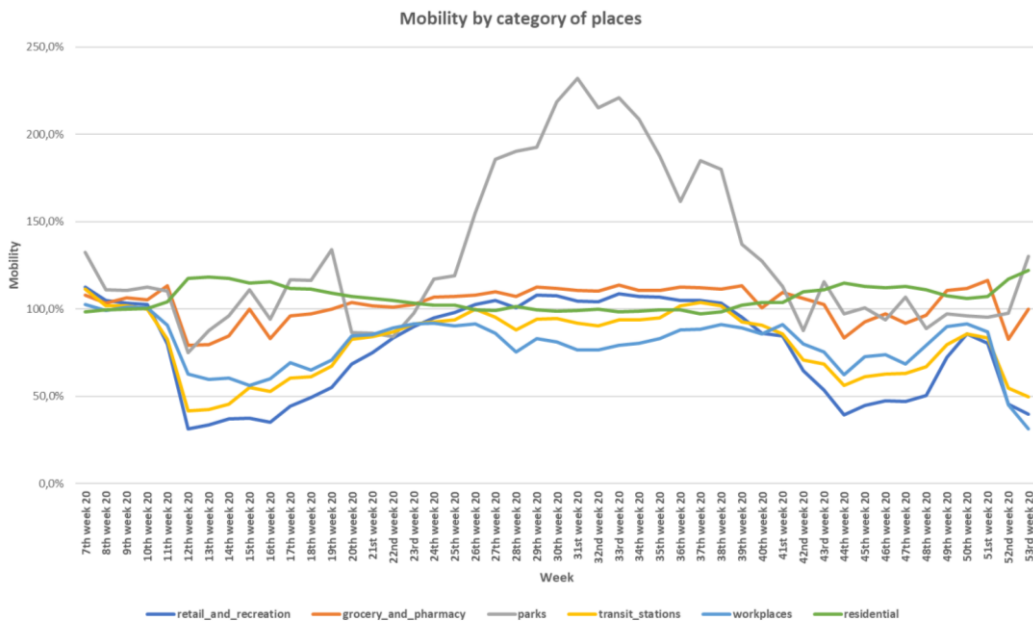
Fig. 1. Google mobility data in the Covid period

During the second pandemic wave, there were two marked opening/closing of retail, so the second wave is analysed in two parts concerning the year – the second wave in 2020 and the wave in 2021. The second wave was significantly more serious in the Czech Republic, so the government also took stricter measures - among the strictest was the closure of the district.

4. Results – Czech crash data
4.1. Crash frequency

Fig. 2 shows the number of crashes in the individual weeks of 2020 and the first five months of 2021 and the average number of crashes in the individual week in the period from 2016 to 2019. The crash frequency was compared with the mobility.

The Pearson correlation coefficient between the mobility data and crash frequency in 2020 reached 0.88 and was statistically significant, which implies a strong association between mobility in general and crash occurrence. The Pearson correlation coefficient for the whole analysed period reached 0.85, in the separate analysis of the 2021 period reached the correlation coefficient 0.74 and in the districts closure period 0.93 (all were statistically significant).

Although the decline in crash frequency and mobility in 2020 was uneven, there is a clear decrease in mobility and crash frequency during both pandemic waves in the Czech Republic. Even though in the first wave the number of infected people and related deaths was lower compared to the second wave, the mobility and crash frequency decreases were higher. The average decrease in the first wave was 22.2% (SD = 16.3), in the second wave in 2020 19.7% (SD = 6.6), and 11,7% (SD = 11.5) in 2021. The reason for a smaller decrease in the second wave may be seen in higher fear and respect and also stricter travel restrictions (especially foreign travel) during the first wave. The 2021 crashes correlation with mobility was smaller during the marked pandemic period, stricter restrictions bring expected mobility and strongly correlated crashes reduction higher than at the beginning of the second wave in 2020.

The influence of the pandemic could be identified not only during waves; there was a slight decrease (Mean = 3.8%, SD = 9.8) also in the period outside waves. Fig. 2 illustrates that the decrease is noticeable at the gradual end of the pandemic restrictions (after the first wave) and also at the gradual onset of restrictions (before the second wave.
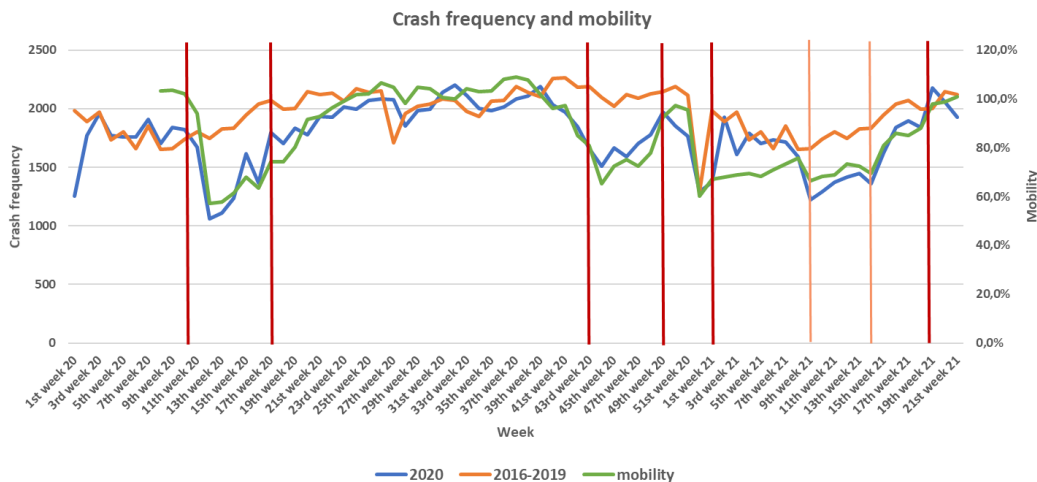
Fig. 2 Crash frequency and mobility

The analysis of crash time distribution in both waves showed no differences. The average percentual change in time distribution was almost zero in both waves (SD = 0.4). The comparison of the crash causes (speeding, inappropriate overtaking, not giving way, inappropriate driving including inattention, not caused by a driver) frequency in 2020 with previous years also achieved minimal differences, both comparing the whole year and in individual waves. The maximum average change in crash-cause frequency for the whole year 2020 period reached 2.5% in "not caused by driver" crashes, which means mostly crashes caused by pedestrians or animals.

4.2. Crash severity

Fig. 3 illustrates the relative change in injury severity between periods from 2016-2019 and years influenced by the Covid pandemic (2020, 2021). The comparison of crashes without injuries and with minor injuries shows slight fluctuations in the range of 0-6%. However, the comparison of severe consequences (serious and fatal injuries) did not show significant deviations. The relative changes in injury severity oscillated between 0-1%. Neither additional analyses of differences for crash participant groups showed any significant differences.

The total decrease in fatalities (within 24 hours of the crash) reached approximately 12%. In 2019, there were 514 fatally injured and in 2020 only 434. The total decrease in the crash frequency was 8.7% (SD = 13.1). Only part of 2021 was analysed, in these 5 months were 156 people fatally injured on Czech roads, which is a decrease of around 6% in comparison with a similar period in 2019.

4.3. Crash participants

For personal vehicles and heavy goods vehicles (HGVs) (Fig.4), there was a noticeable decrease in crash frequency during both waves. Their crash frequency pattern was similar to the pattern of total crashes. The largest decrease could be also observed in the first wave, in the second wave the decrease was smaller by approx. 20%. The highest decrease in personal vehicle crashes is expected to be apparent during districts' closures. Justification of the significant fluctuations and an increase in the frequency of crashes at the beginning of 2021 offers an analysis of the road conditions during crashes, which demonstrates the increase in icy road crashes. Crashes in this period are thus affected by winter conditions and do not reflect a mobility reduction.

A similar trend is visible in the crash frequency of pedestrian and public transport. The decrease was higher compared to personal vehicles and HGVs (Fig. 5). The pedestrian crash frequency reached the highest relative decrease of all crash participant groups, especially in the first wave (Mean = 53.2%, SD = 28.5).

The crash frequency of cyclists and motorcyclists (Fig. 3) showed a different trend. While in the first wave, there could be observed changes in crash frequency during the lockdown, in the second wave the

relative change in crashes oscillated and the crash frequency decrease could not be clearly confirmed during the whole second wave.

Two-wheeled vehicle users' (cyclists, motorcyclists) crash frequency was probably more influenced by seasonality. While the crash frequency of vehicles (personal vehicles and HGVs) and pedestrians was better correlated with mobility data, the cyclist's and motorcyclist's crash frequency was better correlated

with temperature. In the winter season (2021 period) data are correlated similarly to mobility and temperature because in this period two-wheeled vehicles are quite rarely present on the road.

The correlation coefficients of individual crash participant group crash frequencies in relationship with mobility and temperature are listed in Table 1 (bold values indicate statistically significant values).
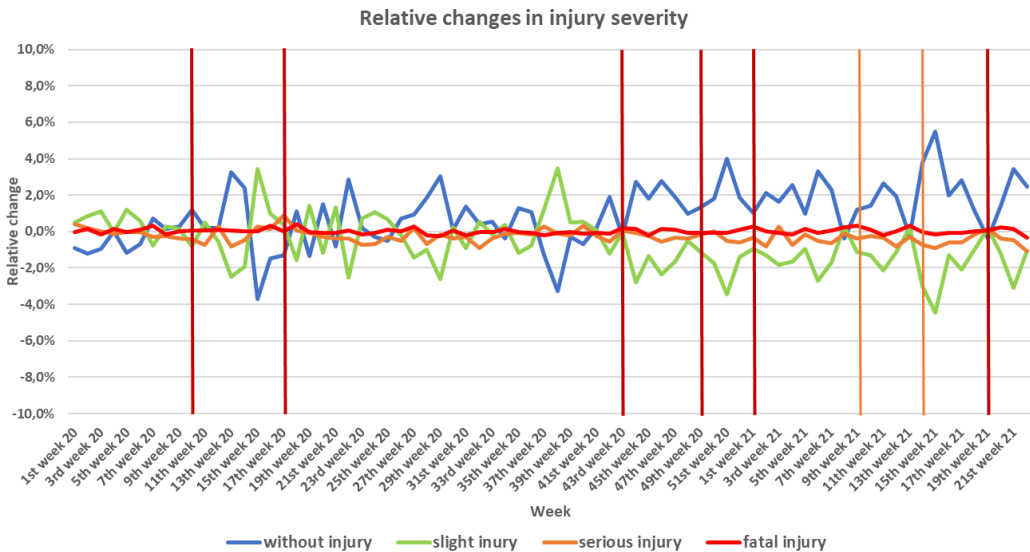

Fig. 3. Relative changes in injury severity

Table 1. Correlation coefficients and achieved significance levels of individual crash participant group crash frequency, temperature and mobility

2020 crash frequency	Temperature	Sig.	Mobility	Sig.
Cyclists	0.94	0.000	0.59	0.000
Motorcyclists	0.91	0.000	0.49	0.001
Personal vehicles	0.57	0.000	0.89	0.000
Heavy goods vehicles	0.37	0.044	0.73	0.000
Pedestrians	0.34	0.038	0.80	0.000
Public transportation	0.25	0.199	0.79	0.000
All groups together	0.65	0.000	0.88	0.000

2021 crash frequency	Temperature	Sig.	Mobility	Sig.
Cyclists	0.85	0.000	0.81	0.000
Motorcyclists	0.84	0.000	0.79	0.000
Personal vehicles	0.32	0.161	0.71	0.000
Heavy goods vehicles	0.09	0.686	0.38	0.091
Pedestrians	0.32	0.156	0.52	0.015
Public transportation	0.05	0.812	0.21	0.364
All groups together	0.38	0.086	0.74	0.000

Similar results are confirmed also by linear regression (Table 2). Linear regression was used to determine statistical associations between the crash frequency and mobility or weather conditions. The regression coefficients are interpreted as the effect of each variable on crash frequency if all other explanatory variables are held constant. Almost all models achieved $R^2>0.5$, except pedestrian crashes in 2021 ($R^2=0.27$), the crash frequency models for HGV and public transport were not significant. The higher quality achieved by cyclists and motorcyclists models, which also achieved higher value of correlation coefficients (>0.9) related to temperature.

Table 2. Regression coefficients and achieved significance levels of individual crash participant group crash frequency, temperature and mobility

2020 crash frequency	Constant	Temperature		Mobility		R^2	Sig.
		Beta coefficient	Sig.	Beta coefficient	Sig.		
Cyclists	2.389	7.305	0.000	-	-	**0.873**	**0.000**
Motorcyclists	-14.760	6.989	0.000	-	-	**0.823**	**0.000**
Personal vehicles	307.375	-	-	1427.947	0.000	**0.780**	**0.000**
Heavy goods vehicles	111.285	-	-	216.908	0.000	**0.499**	**0.000**
Pedestrians	-26.525	-0.451	0.091	90.086	0.000	**0.661**	**0.000**
Public transportation	-18.972	-0.719	0.004	85.661	0.000	**0.666**	**0.000**
All groups together	526.664	9.580	0.006	1306.311	0.000	**0.814**	**0.000**

| 2020 crash frequency	Constant	Temperature		Mobility		R^2	Sig.
		Beta coefficient	Sig.	Beta coefficient	Sig.		
Cyclists	-52.886	3.472	0.004	113.435	0.030	**0.873**	**0.000**
Motorcyclists	-59.451	3.374	0.005	98.434	0.061	**0.755**	**0.000**
Personal vehicles	-358.159	-25.246	0.033	2509.345	0.000	**0.619**	**0.000**
Heavy goods vehicles	65.917	-	-	-	-	-	-
Pedestrians	6.880	-	-	46.203	0.015	**0.272**	**0.015**
Public transportation	47.381	-	-	-	-	-	-
All groups together	-150.850	-20.855	0.081	2477.677	0.000	**0.621**	**0.000**
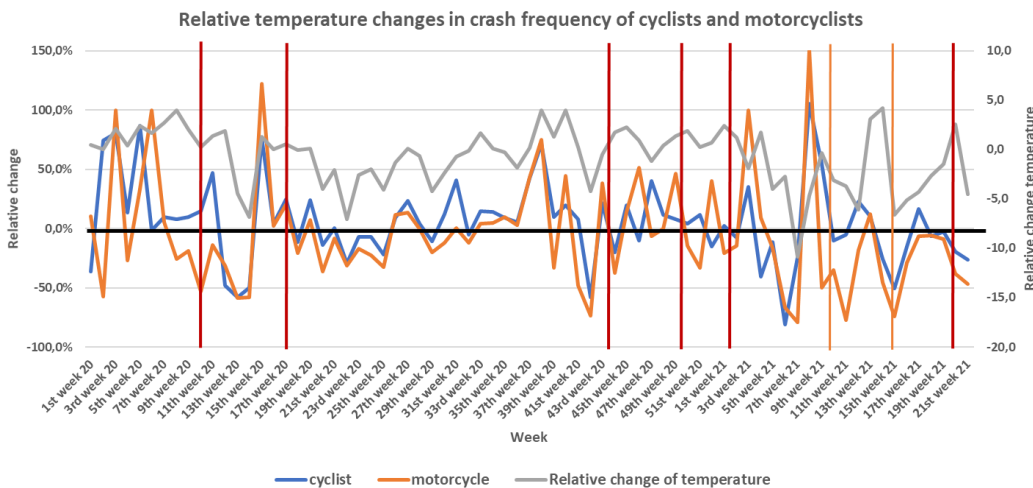
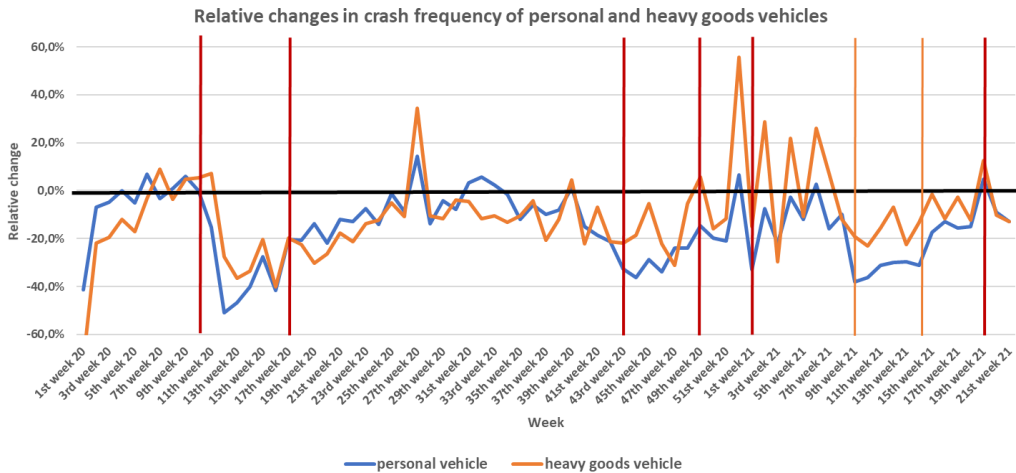Fig. 4 Relative changes in crash frequency of cyclists and motorcyclists

Fig. 5 Relative changes in the crash frequency of personal and heavy goods vehicles
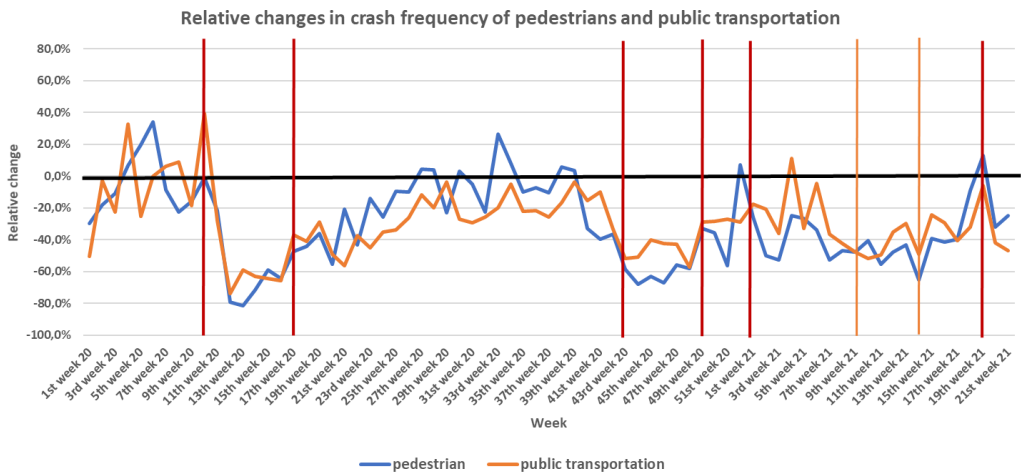

Fig. 6 Relative changes in the crash frequency of pedestrians and public transportation

A closer look into the crash frequency of cyclists and motorcyclists in the first wave (Fig. 4) shows that the crash frequency during lockdown oscillates. The significant increase in cyclists' and motorcyclists' crash frequency was connected with a significant temperature increase. The comparison of both pandemic waves and crash frequency of selected crash participants is illustrated in Table 3.

Restrictions related to international mobility are reflected by data on crashes involving foreign vehicles not registered in the Czech Republic. In the first wave, international mobility was limited in most countries. The crash frequency of passenger cars registered outside the Czech Republic decreased by up to 80% (Mean = 71.9%, SD = 24.9), and HGVs registered outside the Czech Republic up to 60% (Mean = 21.9%, SD = 35.4). The second wave also brought restrictions to international transport, but it mainly concerned travel for personal purposes. The decrease in crash frequency of foreign vehicles was thus lower than in the first wave. The crash frequency decrease involving non-Czech passenger cars was 59% on average (SD = 10.8) in 2020 and 56.3% (SD = 11.1) in 2021 period and non-Czech HGVs crash frequency 19.6% on average (SD 17.8) in 2020 and only 1.1% (SD = 22.0) in 2021 period.

Table 3. Crash frequency of crash participants during the whole period and both waves

All weeks	Cyclists	Motorcyclists	Personal vehicles	Pedestrians	Heavy goods vehicles	Public transportation
Average	5.3%	-5.0%	-15.0%	-29.3%	-10.7%	-29.2%
SD	34.6%	46.0%	14.4%	26.2%	17.8%	21.3%

1st wave 2020	Cyclists	Motorcyclists	Personal vehicles	Pedestrians	Heavy goods vehicles	Public transportation
Average	1.2%	-8.8%	-30.3%	-53.2%	-20.7%	-43.9%
SD	49.2%	60.5%	17.6%	28.5%	18.1%	37.1%

2nd wave 2020	Cyclists	Motorcyclists	Personal vehicles	Pedestrians	Heavy goods vehicles	Public transportation
Average	10.1%	15.2%	-27.7%	-57.5%	-14.1%	-44.9%
SD	20.4%	32.4%	7.4%	11.8%	12.8%	9.4%

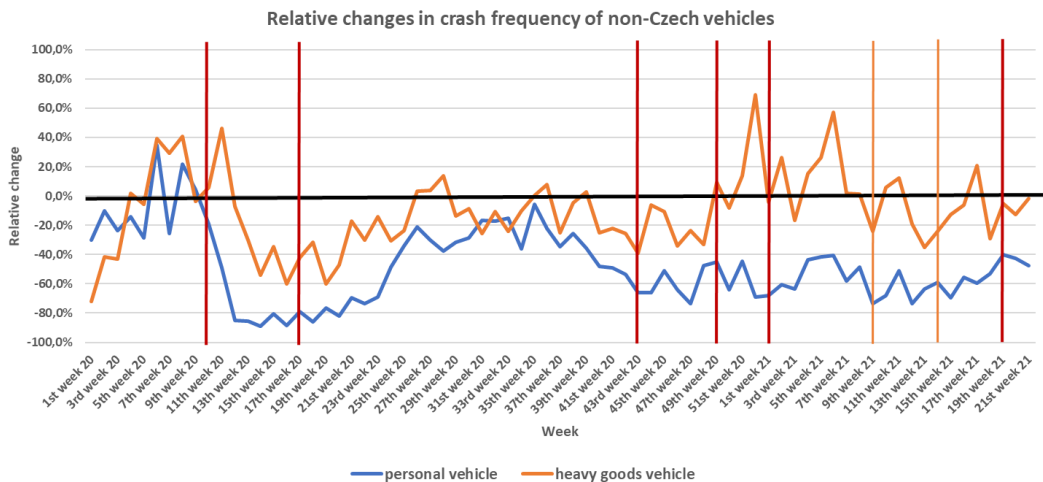| 1st wave 2021	Cyclists	Motorcyclists	Personal vehicles	Pedestrians	Heavy goods vehicles	Public transportation
Average	-1.8%	-14.5%	-18.6%	-38.4%	-5.2%	-30.3%
SD	40.0%	57.4%	13.0%	18.0%	17.0%	16.8%

Fig. 7 Relative changes in the crash frequency of foreign (non-Czech) vehicles

5. Discussion and conclusions

Covid negatively influenced several aspects of our life. Despite all the negative impacts of the pandemic, the decrease in crash-related injuries could be seen as one of the positive impacts of stay-at-home policies. One of the positive impacts of the Covid lockdown was not only a decrease in crash frequency but also a decrease in air pollution (Brodeur, 2020).

The main purpose of this work was to investigate the pandemic impact on road safety in the Czech Republic. The reviewed studies showed different trends in crash frequencies during the Covid lockdown. The crash data from the Czech Republic shows a reduction in crash frequencies similarly as, e.g., Alhajyaseen et al. (2022), Doucette (2020), Saladie et al. (2020), Qureshi et al. (2020), Lin et al. (2021), Hughes et al. (2020), Oguzoglu (2020), Vandoros (2022). Even though several previous studies reported an increase in severe injuries, the Czech data did not prove a significant change in severities: the relative change of severe consequences (serious and fatal injuries) oscillated between 0% and 1%.

Compared to most previous studies, the presented study focused not only on the overall crash frequency but also on the analysis of the crash frequency according to the individual crash participants such as cyclists, motorcyclists, personal vehicles, heavy goods vehicles, pedestrians and public transportation. The analysis of participant groups may be beneficial also for the identification of people who tend to violate Covid restrictions and for assisting professionals to improve response to these countermeasures. The crash numbers could also reflect changes in the way how people spend time, respectively increase in leisure time activities in some of the age groups (especially students). These changes may lead to differences in the frequency in the crash participant groups and are also related to the change in the usage of various transport modes.

To analyse whether these differences in crash frequencies were affected more by mobility decrease or seasonality, the crash frequency of defined road user types was analysed in relation to mobility data and temperature. Two-wheeled vehicles (cyclists and motorcyclists) crash frequency was more influenced by seasonality and was better correlated with temperature. With a decrease in mobility in the second wave, there were oscillations in the crash frequency of cyclists and motorcyclists, but not a clear decrease in the crash frequency of these vehicles as it was with vehicles and pedestrians. The increase in bicycle use during the first lockdown which was not maintained into the colder weather in autumn was described also by Vickerman (2021) in the UK. Brodeur (2020) also provided evidence that crash reduction is driven partly by reduced travel associated with stay-at-home orders and by distributional changes to traffic times. In comparison, there were no significant changes in the time distribution of crash time in the Czech crash data. There were no significant perceptual changes in time distribution (almost zero in both waves), which indicates that part of the population adhered to stay-at-home politics (distance learning, home office). While two-wheeled vehicle crashes were significantly affected by the mobility reduction due to the Covid pandemic, but rather by the weather conditions, the HGV and public transport crashes seasonality does not affect. Differences in 2020 and 2021 confirm the influence of pandemic restrictions – HGV crashes were influenced by mobility in 2020, because of the travel abroad limitation. The highest correlations

with mobility achieved personal vehicle crashes. Correlation with temperature and/or mobility and regression model demonstrate that the crash types may be affected by reduced mobility as a safety countermeasure. The mobility reduction brought the most significant decrease in pedestrian crashes. The results suggest that measures aimed at vehicle-pedestrian interaction, or the modification of pedestrian infrastructure, may thus contribute to pedestrian crash reduction.

As usual, the main limitation of this study was in the used dataset. Police statistics do not include all crashes and some factors (such as impact speed) are not part of these data. This is also why factors such as age, gender, or infrastructure (e.g., road type) were not considered in this study. The future analysis could be supplemented by data from observational studies, which may better indicate trends in risky behaviour such as the use of mobile phones, seat belts, or speeding.

Crash data from the Czech Republic during the Covid pandemic did not indicate large changes in risky behaviour. The mobility decrease was associated with a decrease in crash frequency, especially of vehicles and pedestrians. The change in mobility and necessity of isolation connected with nice weather (higher air temperature) was associated with an increase in two-wheeled vehicle crashes. The crash frequency of cyclists and motorcyclists could be seen as one of the longitudinal impacts on people substituting social activities during the Covid lockdown. The higher correlation of cyclists' and motorcyclists' crash frequency with temperature than with mobility itself can serve as support for the definition of a time frame for targeted repressive measures and communication campaigns.

The analysis of factors related to the change in crash trends, characteristics, and crash frequency decrease may provide new insights and help target countermeasures for road safety improvement. The results of this study could also help with the definition of adjustments in traffic regulation to prevent the risky behaviour and its serious consequences during future pandemics and also concerning necessary pandemic restrictions (e.g., a decrease of the posted speed limit, increase in preventive police surveillance focused on alcohol and speed). Based on the results it may be concluded that it is not sufficient to generalize findings across individual countries.

While some countries experienced an obvious increase in severe consequences, some countries indicated a decrease or stable severity rate. It is thus necessary to consider the tendency towards risky behaviour concerning national or local restrictions.

Acknowledgement

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