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Factors affecting road traffic crashes with drivers with disabilities who use hand controls in a less developed country

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ABSTRACT

One of the most common vehicle modifications is the installation of hand controls that allow persons who are unable to operate the brake and accelerator pedals with their feet due to physical impairment to drive. Considered the specifics of hand controls (higher workload during driving and lower passive safety), it is very important to analyze the safety of the category of drivers with disabilities who use them. This paper aims to determine which factors influence the participation in road traffic crashes of drivers with disabilities who use hand controls. Based on the identified factors, measures and activities are defined to improve the road safety of drivers with disabilities who use hand controls, to improve the mobility of persons with disabilities, and to encourage potential drivers with disabilities, especially in less developed countries. The research was conducted in Serbia, which belongs to the group of less developed countries in the world. Considering the estimated number of drivers with disabilities who use hand controls, every fourth driver in Serbia participated in the survey (65 respondents). The statistical analysis was performed by the decision tree CART algorithm. Driving experience with hand controls is the most important variable of the participation of drivers with disabilities in a road traffic crash while driving vehicles with hand controls. Improving the system of maintaining hand controls, harmonize the performance of hand controls with the medical status of the drivers with disabilities, improving awareness of drivers with disabilities about risky behaviors in traffic are recognized as the most important measures and activities.

1. Introduction

The United Nations has recognized persons with disabilities (PWD) in the Convention on the Rights of Persons with Disabilities (Convention on the Rights of Persons with Disabilities and Optional Protocol, 2006) as „those who have long-term physical, mental, intellectual or sensory impairments which in interaction with various barriers may hinder their full and effective participation in society on an equal basis with others". PWD represent a significant group of the population. According to the report of the World Health Organization (2011), they are 15.6% of the world's population.

In the European Disability Strategy 2010-2020 (European Commission, 2010) the most important of the eight areas for action is Accessibility. In this area of action, the problem of access to transportation is especially highlighted as an important topic for PWD. Namely, PWD have an average of 2.6 trips per day, which is one trip less than the average of other residents (Brumbaugh, 2018). Similarly, Henly and Brucker (2019) found that the average number of trips for PWD (who have a trip during a day) is 3.9 and slightly less than for other residents - 4.2. Reduced mobility of PWD negatively affects their social life (shopping, meals, errands, recreational, etc) as well as the possibility of employment (Brumbaugh, 2018; Grisé et al., 2019). Even sixty-seven percent of PWD recognized that lack of access to transportation hindered their social life (Bascom & Christensen, 2017). One way to improve mobility and access to transportation is to enable independently driving the private vehicle. Independently driving the private vehicle was proved as an extremely important factor in socialization and improving the quality of life of PWD (Darcy & Burke, 2018; Giordani & Dijkers, 2011; Hutchinson, Berndt, Gilbert-Hunt, et al., 2020; Lee et al., 2018; Norweg et al., 2011; Ramakrishnan et al., 2011; Tsai et al., 2014).

Many PWD can independently drive a private vehicle. In specific situations, some modifications to the vehicle are necessarily made. One of the most common vehicle modifications is the installation of hand controls (HC) (Biering-Sørensen et al., 2004; Dahuri et al., 2017; Di Stefano et al., 2015; Henriksson & Peters, 2004). Pilkey et al. (2001) defined HC as: "devices used by people who are unable to operate the brake and accelerator pedals with their feet due to physical impairment". Drivers with disabilities (DWD) who drive a vehicle with HC are mostly or very satisfied with HC (Di Stefano et al., 2015). Also, the social return of investment of vehicle (among other things, installation of HC) is up to $17.3 for every $1 invested (Hutchinson, Berndt, Cleland, et al., 2020). The installation of HC can increase the workload during driving (Benoit et al., 2009) and the reaction time (Peters, 2001) at DWD. Additionally, there are some concerns about the impact of HC on the passive safety of a driver in a road traffic crash. The presence of HC in the vehicle increases the risk of injury to the driver's knee (Pilkey et al., 2001; Schneider et al., 2016) and disputes the effectiveness of airbags (Hu et al., 2020).

Previous studies did not find statistically significant differences in the risk of participation in road traffic crashes of drivers with disabilities (DWD) and drivers without disabilities (Henriksson & Peters, 2004; Prasad et al., 2006; Sagberg et al., 2003). Considered the mentioned specifics of HC (lower passive safety and higher workload during driving), it is very important to analyze the category of DWD who use HC during driving.

In order to reduce the number of road traffic crashes of DWD, improve mobility of PWD, and encourage potential DWD, it is necessary to investigate the factors that influence the occurrence of road traffic crashes. This paper aims to determine which factors influence the participation in road traffic crashes of DWD who use HC. The research was conducted in Serbia, which belongs to the group of less developed countries in the world. The specificity of these countries is a higher number of PWD (WHO, 2011), poorer equipment of modified vehicles compared to highly developed countries (Lee et al., 2018), which results in fewer DWD. With the future development of less developed countries, a significant increase in the number of DWD can be expected. Considering the specifics of the observed group of drivers (Benoit et al., 2009; Hu et al., 2020; Peters, 2001; Pilkey et al., 2001; Schneider et al., 2016) and the situation in less developed countries (Lee et al., 2018), this topic is extremely important. Based on the identified factors, measures and activities are defined to improve the road safety of DWD who use HC, to improve the mobility of PWD, and to encourage potential DWD, especially in less developed countries.

2. Methodology

2.1. Research area

According to The National Organization of Persons with Disabilities of Serbia (2020), 870,000 PWD live in Serbia, which is about 12.6% of the population. Although every eighth inhabitant of Serbia is a person with a disability, PWD represent a very marginalized group in the population. Based on the 2011 Census (The Census of Population, Households and Dwellings in the Republic of Serbia), Marković (2014) especially emphasizes the problem of economic activity and inaccessibility of education of PWD. Additionally, the report of The Academic Network of European Disability Experts – ANED (2018) shows that Serbia significantly falls behind highly developed European countries in terms of the inclusion of PWD in society.

DWD are not recognized as a specific group of road users, so their exact number in Serbia is unknown. Also, the number of DWD who use HC is unknown. However, experts (experts from national institutions, non-government organizations of PWD, and universities) estimate that the number is around 250. The relatively small number of DWD who use HC is a consequence of numerous barriers and problems. The most significant barriers and problems that PWD have in the process of obtaining a driver's license in Serbia (RTSA, 2019) are as follows:

- **Determining the functional ability to drive**. The problem is the competence of general practitioners to assess whether a person with a disability can drive safely.

- **Driver training and retraining process**. A small number of driving schools provide safe training for potential DWD (only 3 driving schools in the whole country). The absence of an organized retraining process of drivers who previously drove a conventional vehicle.

- **Modification of a private vehicle**. In practice, the vehicle modifications are uniform and represent the installation of standardized HC, without potential individual adjustments. There is a need for a multidisciplinary approach when determining the necessary vehicle modifications for each person with a disability (Petrović et al., 2020).

- **Financial support**. The absence of significant financial support during the process of driver training, purchase, and modification of a private vehicle.

2.2. Research design

The questionnaire used for this research is composed of questions divided into four groups. The first part of the questionnaire consisted of questions about sociodemographic status.

The next group of questions refers to the medical status of the respondents. In this part, the respondents stated about the functional limitations of parts of the body and the reason for disability. Also, the respondents had the opportunity to explain in more detail the specifics of their medical status.

The third group of questions is related to the DWD's driving and includes questions related to the vehicle, modifications of the vehicle, process of driving training, and driving habits. As part of the vehicle-related questions, the respondents stated the characteristics of their vehicles, such as vehicle type, vehicle age, and transmission type. Further, the respondents listed the modifications that were made to their vehicle. For each modification, the respondents pointed out how many years they have been using it and how satisfied they are with it. The respondents also shared their experiences related to the driver's training and retraining process. Here, the respondents stated when they passed the driving test, the type of the driving school's vehicle and whether they had certain retraining. Questions related to the driving habits of the respondents referred to the frequency of driving, average annual mileage, and driving start circumstances. According to Di Stefano et al. (2015), the respondents assessed the impact on a drive starting of the existence of parking spaces for PWD, night conditions, traffic jams, weather conditions, faraway and unknown locations on a five-point Likert scale.

The fourth group of questions refers to the road safety of DWD. As part of the questions from this group, the respondents stated whether they participated in road traffic crashes as drivers who use HC and if so, they briefly described the road traffic crashes. Also, the respondents agreed on a five-point scale towards several risky behaviors in traffic in terms of road safety. The questions were modeled on the SARTRE 4 questionnaire (Antov et al., 2010) and included questions related to seat belt use, speeding by more than 20 km/h in a settlement, passing the yellow light, driving after alcohol consumption, using a mobile phone while driving and starting to drive despite fatigue.

2.3. Participants

In order to find DWD who use HC, the first step was to contact representatives of the Union of Persons with Paraplegia and Quadriplegia of Serbia - UPPQS. In the previous period, this non-government organization has implemented several projects related to DWD who use HC (UPPQS, 2020). The representatives of UPPQS enabled contact between ten DWD who use HC and the authors to realize a pilot study. Based on the pilot study, the research procedure and the final version of the questionnaire were defined. After that, the collection of the sample was performed with the help of the representatives of UPPQS and the respondents who suggested other DWD who use HC (snowball sampling method).

The research was conducted by interviewing the respondents by the authors. Interviews were conducted by face to face or telephone, depending on the capabilities and wishes of the respondents and taking into account health protocols due to the pandemic of the COVID-19. In the beginning, each respondent was acquainted with the aim of the research and the authors' work. Initial introductions were taken between five and ten minutes. After the initial introduction, each respondent was asked whether it wants to participate in the research and whether it gives their consent that the collected data could be used by the authors for the research. If the respondent gave the consent, the author would start interviewing based on the verified questionnaire. The average interview time of the respondents was between 20 and 25 minutes.

The research was conducted on the territory of Serbia during September and October 2020. During the research, 82 DWD who use HC were contacted, of which 65 agreed to participate in the research, which represents a response rate of 79.3%. Considering the estimated number of DWD who use HC, every fourth DWD who use HC in Serbia participated in the survey.

According to the obtained results, most DWD who use HC are male. The average age of the respondents is 42.9 years. The respondents most often live in urban areas (50.8%), have low monthly incomes (below €500) (56.9%), have a high school graduate or lower (67.7%), are unemployed (66.2%), and most often live in two-member or three-member families (60). The most common reason for disability is road traffic crashes, in 49.2% of respondents. The highest degree of functional limitation is observed in the lower extremities of the respondents (left/right thigh, lower leg, and foot), over 95%. Also, a significant number of respondents have certain functional limitations of the spine/back and abdominal muscles, over 65%.

2.4. Statistical analysis

After interviewing the respondents, the last step in the research was to conduct a statistical analysis. The statistical analysis was performed in three parts. First, descriptive statistics describe the basic characteristics of the respondents in terms of their participation in traffic (Chapter 3.1.). The dependent variable in the research is a binary type variable that shows the participation of the respondents in a road traffic crash while driving a vehicle with HC.

In the last part of the analysis, a decision tree algorithm was applied to identify groups of respondents who have a higher risk of participating in road traffic crashes. By the decision tree method analyzed all variables conducted during research. Considering the sample size and Royall (1986) recommendation, the value of the significance level is set up at 90%. Since the independent variables are of different types, the CART algorithm (Breiman et al., 1984) was used, with the following parameters: a minimum of 20 answers on a parent node, 10 answers on a child node, and Gini splitting criterion.

3. Results

3.1. Driving characteristics of DWD

3.1.1. Vehicle and modifications

The average age of vehicles with HC in the Republic of Serbia is 13.4 years. Manual transmission have 15.4% of vehicles, although automatic transmission is common in vehicles with HCs. In addition to HCs, 9.2% of respondents have embedded steering assist devices on the steering wheel.

The average use of HCs is 12.5 years, and steering assist devices is 10.3 years. Satisfaction with both devices on a five-point scale is very high, over 4.5. Regarding the procedure of installing HCs, the respondents point out the high costs of devices, high installation costs, and the small number of professional services that install this type of device.

3.1.2. Training and retraining process

Although the average use of HCs is 12.5 years, the driving experience of the respondents is longer - 19.9 years. The reason for this difference is that the majority of respondents (61.5%) have driving experience in conventional vehicles, before acquiring a disability. The remaining 38.5% of respondents took the driving test on a vehicle with HC.

Only 12.5% of respondents who took the driving test on a conventional vehicle had some retraining in adapting to HC (7.7% of respondents from the total sample - Figure 1). The respondents described that the retraining involved private lessons with driving instructors on their private vehicle with HC.

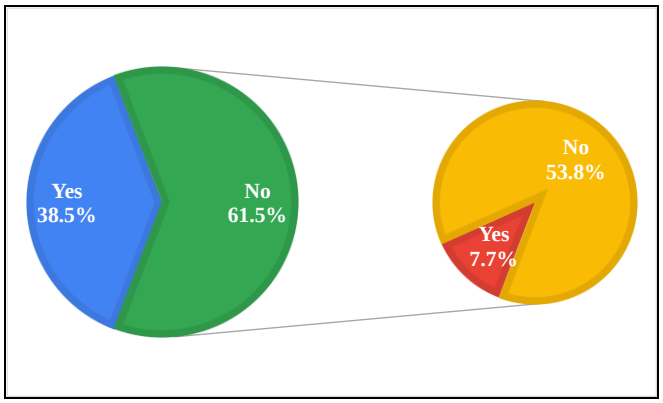

Figure 1. Left pie: "Have you passed the driving test on a vehicle with hand controls?"; Right pie: "Have you had retraining in adapting to a vehicle with hand controls?"

3.1.3. Driving habits

The majority of respondents drive every day (80.0%), while significantly fewer of them drive several times a week (13.8%) or several times a month (6.2%). Even 27.7% of respondents said that they participated in at least one road traffic crash in the period since they used HC. The respondents most often participated in one road traffic crash (Figure 2).

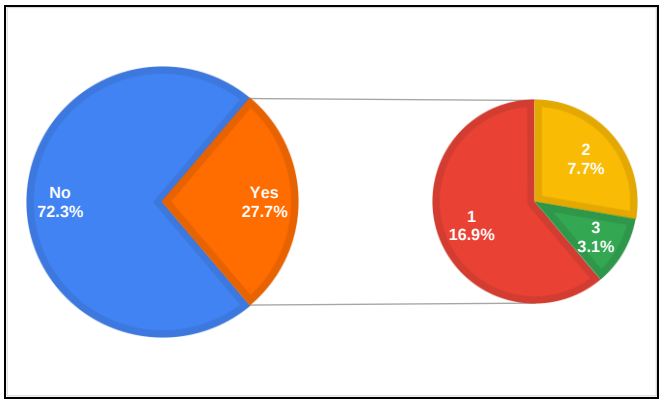

Figure 2. Left pie: "Were you participated in a road traffic crash while driving a vehicle with hand controls?"; Right pie: "How many road traffic crashes have you been participated in?"

The most common reason why the respondents avoid driving is bad weather and traffic jam during peak hours (Figure 3). On the other side, the existence of parking spaces for PWD has a very positive impact on the respondents. **Error! Reference source not found.** shows the attitudes towards risky behavior in traffic of the respondents in traffic in terms of road safety. The respondents have a very positive attitude towards seat belt use, and on a 5-point scale, they rate it at 4.95. On the other side, the use of mobile phones while driving is the most worrying behavior.

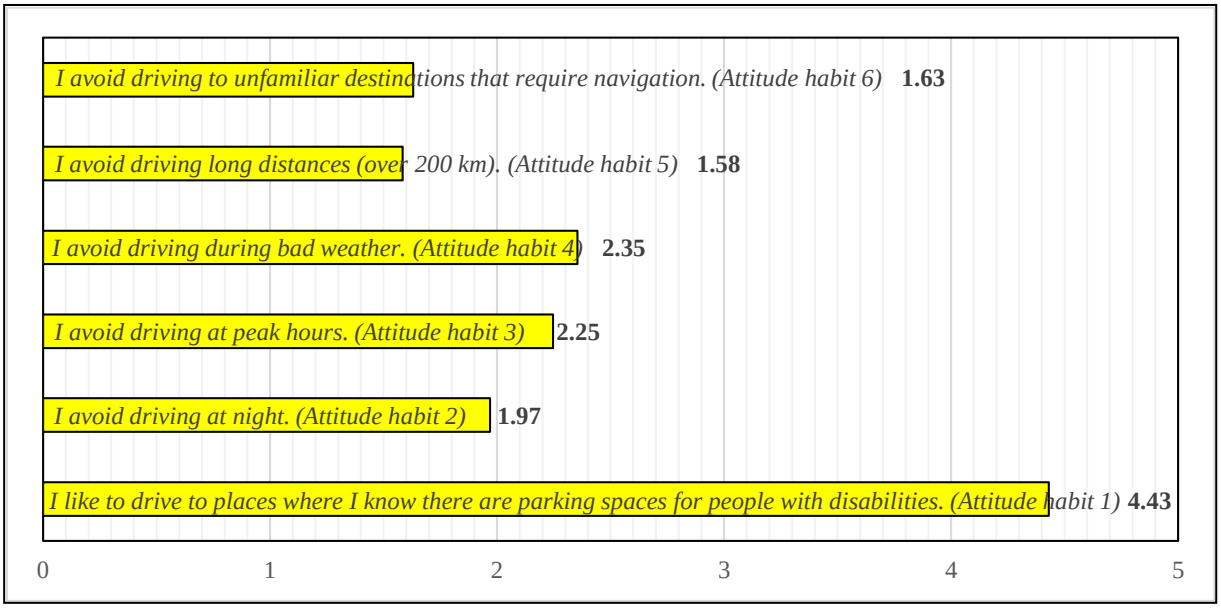

Figure 3. Attitudes towards driving start circumstances

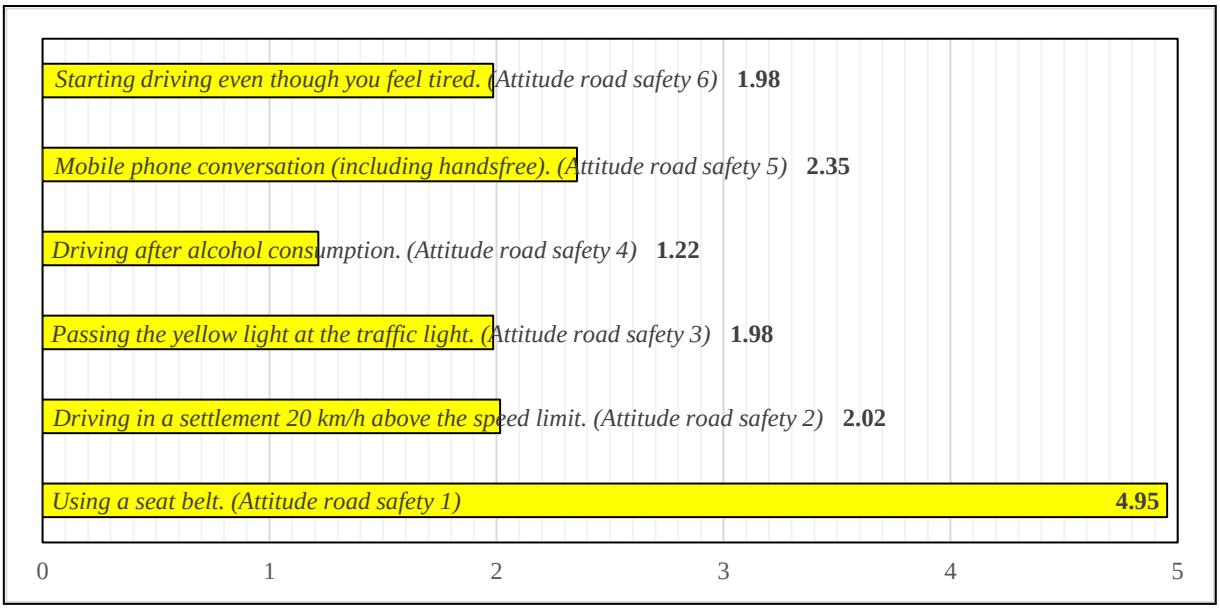

Figure 4. Attitudes towards risky behavior in traffic

3.2. Participation in road traffic crashes

3.2.1. Identification of risk groups

Creating a decision tree applying the CART algorithm aims to identify the risk groups of the respondents and identify factors that differentiate these groups. Based on the created decision tree (Figure 5), driving experience in using HC has the most significant impact on participation in a road traffic crash. Namely, the respondents who use HC for less than 7.5 years involved in road traffic crashes of less than 5%.

On the other side, the respondents who use HC longer than the mentioned margin participated in a road traffic crash at 33.6%. Further branching of the decision tree with more experienced DWD shows a significant impact of the variable Attitude road safety 6. Even 75% of more experienced DWD who are more likely to start driving despite fatigue participated in a road traffic crash. The respondents who were not prone to start driving when they felt tired participated in road traffic crashes at 25%.

4. Discussion and conclusion

Driving experience with HC is the most important variable of the participation of DWD in a road traffic crash while driving vehicles with HC. DWD who use HC for over 7.5 years are more likely to be involved in a road traffic crash. This finding is logical considering that DWD who have more experience with HC are more exposed to traffic. However, other specifics need to be considered. First, poorer quality of older HC due to inadequate and unprofessional maintenance and expensive replacement for new HC. This finding is also confirmed by the respondent who has 22 years of driving experience with HC (Male, 40):

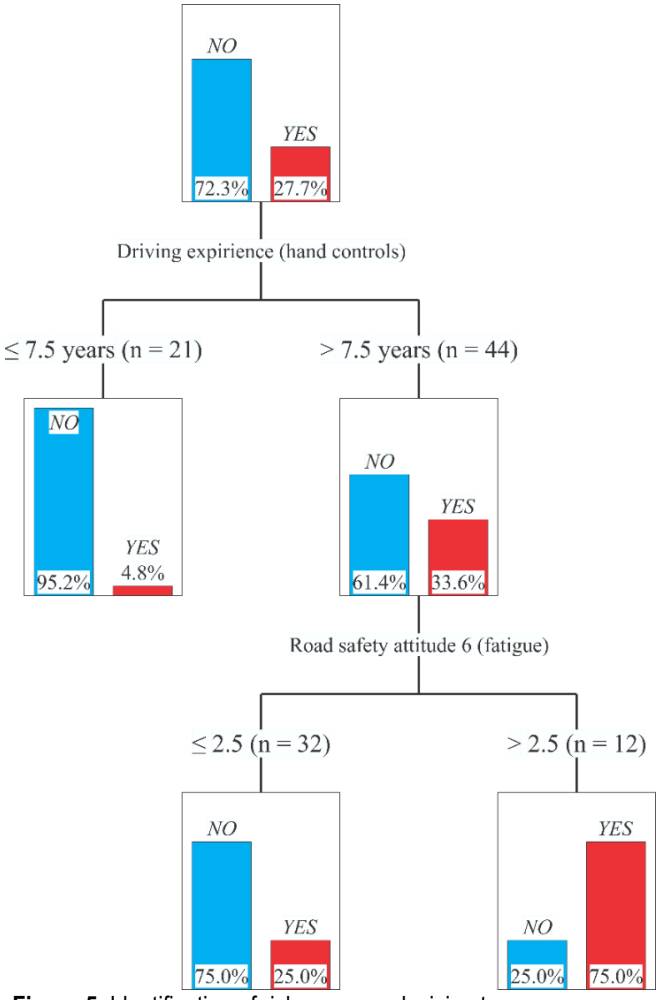

Figure 5. Identification of risk groups – decision tree

"*The problem is the lack of services which install and maintain hand controls and other modifications for the driver with disabilities, because of that drivers with disabilities are often forced to maintain hand controls themselves*" and the respondent who has 13 years of driving experience with HC (Male, 40): "*Installation of hand control is fast, but the biggest problems are the costs of the device and installation*". High costs of the installation of HC is identified as the most significant barrier to their accessibility to DWD (Darcy & Burke, 2018; Woodbury, 2012). Specifically for the research area, the respondents point out a very small number of services for installation and maintaining HC and their poor spatial distribution. To solve these problems, it is necessary to improve the system of maintaining HC and provide support (financial and advisory) to DWD. Second, the medical status changes over time may be related to their driving abilities. The change in the medical status can lead to a situation where previously installed HC are not satisfactory for DWD, so driving tasks become more demanding for them, which increases their risk of participating in a road traffic crash. These are some of the main causes of road traffic crashes for DWD who use HC. Namely, the DWD was unfamiliar with the equipment, the modification did not sufficiently satisfy the individual need and the equipment broke down were the direct causes of almost 10% of road traffic crashes at DWD (Henriksson & Peters, 2004). Conducting regular medical tests of DWD could significantly reduce the risk of participating in road traffic crashes (Koppel et al., 2019). Orderly adjustment of the performance of HC in accordance with medical needs of the DWD should be realized.

In terms of road safety, the only one risky behavior showed a statistically significant impact on the dependent variable, that is fatigue and the use of mobile phones while driving. Fatigue has a particularly significant impact on drivers with more experience with HC (over 7.5 years). The increase of complexity in driving due to changes in the medical status of the drivers and changes in the performance of HC may be the reason for this finding. Considering that tired drivers have poorer driving performance and a higher risk of participating in a road traffic crash (Davidović et al., 2018; Kwon et al., 2019; Liu & Wu, 2009), this is a serious problem. The importance of fatigue is also shown by Moradi et al. (2019), the authors state that drivers who drive tired are 1.29-1.34 times more likely to participate in a road traffic crash.

Based on the conducted research measures and activities are defined to improve the road safety of DWD who use HC, to improve the mobility of PWD, and to encourage potential DWD:

- **Improving the system of maintaining HC.** Establishing a system of continuous quality monitoring of HC and providing support to DWD (financial and advisory) for active participation in the system.
- **Harmonize the performance of HC with the medical status of the DWD.** Orderly adjustment of the performance of HC in accordance with the medical status of the DWD.
- **Improving awareness of DWD about risky behaviors in traffic.** Implementation of education and training in simulators to point out risky behaviors in traffic (primarily the impact of fatigue and the use of mobile phones).

During the research process, certain limitations were noticed. Unfortunately, PWD are not recognized in the system of recording road traffic crashes in Serbia. For this reason, the only way to obtain information about road traffic crashes with PWD is by interviewing them. This can be a potential limitation in terms of socially acceptable responses of the respondents. The absence of official records also limits the availability of variables related to the road and the environment characteristics at the time of the road traffic crash. Another limitation is the small number of DWD who use HC due to the generally poor inclusion of PWD in Serbian society. This limitation affects the reduced availability of adequate statistical tools, and thus a smaller number of reliable conclusions.

Future researches should monitor the further development of mobility of PWD and the state of their road safety, especially in less developed countries. The contribution of the medical status of DWD to the occurrence of a road traffic crash should be specifically investigated. Finally, models should be created as a quantitative measure of the ability of DWD to drive a vehicle.

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