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Characteristics of single-vehicle crashes with e-bikes in Switzerland

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ABSTRACT

In Switzerland, the usage and accident numbers of e-bikes have strongly increased in recent years. According to official statistics, single-vehicle accidents constitute an important crash type. Up to date, very little is known about the mechanisms and causes of these crashes. To gain more insight, a survey was conducted among 3658 e-cyclists in 2016. The crash risk and injury severity were analysed using logistic regression models. 638 (17%) e-cyclists had experienced a single-vehicle accident in road traffic since the beginning of their e-bike use. Risk factors were high riding exposure, male sex, and using the e-bike mainly for the purpose of getting to work or school. There was no effect of age on the crash risk. Skidding, falling while crossing a threshold, getting into or skidding on a tram/railway track and evasive actions were the most important accident mechanisms. The crash causes mentioned most often were a slippery road surface, riding too fast for the situation and inability to keep the balance. Women, elderly people, riders of e-bikes with a pedal support up to 45 km/h and e-cyclists who considered themselves to be less fit in comparison to people of the same age had an increased risk of injury. This study confirms the high relevance of single-vehicle crashes with e-bikes. Measures to prevent this type of accident could include the sensitisation of e-cyclists regarding the most common accident mechanisms and causes, a regular maintenance of bicycle pathways, improvements regarding tram and railway tracks and technological advancements of e-bikes.

1. Introduction

In Switzerland, annual sales of e-bikes (electrically assisted bicycles, also called pedelecs) have significantly increased in recent years. While about 3000 e-bikes were sold in 2006, this number increased to over 75,000 in 2016 (velosuisse, 2017). Not surprisingly, more and more accidents with this means of transport have been registered over time: between 2011 (the first year in which the category *electric bicycle* was included in the Swiss police reports) and 2016, the numbers of injured e-cyclists in police reports have more than tripled to a total of almost 700 in 2016 (Uhr and Hertach, 2017). The official statistics also show that single-vehicle accidents are an important crash type for e-cyclists: about half of the registered accidents (road traffic) in the past 5 years took place without collision with another road user (Uhr and Hertach, 2017). Moreover, it can be assumed that single-vehicle crashes are much more common in reality since a large part probably remains unreported to the police. In order to prevent this type of accident, details on the mechanisms and causes of these crashes are needed. Unfortunately, police reports do often not provide detailed information concerning this matter. In addition, only few scientific studies have so far investigated this issue, most of which only included a limited number of accidents (Jellinek et al., 2013; Lawinger and Bastian, 2013; Papoutsi et al., 2014; Schepers et al., 2014; Alrutz et al., 2015; Johnson and Rose, 2015a; Boele-Vos et al., 2017). Due to different definitions of single-vehicle accidents and a heterogenous selection and categorisation of crash mechanisms and causes, a comparison of the results of these studies is very difficult (Uhr and Hertach, 2017).

In 2016, we conducted a survey among e-cyclists in the German-speaking part of Switzerland. The main aim of this study was to gain more knowledge on the characteristics of single-vehicle crashes with e-bikes in road traffic. In addition, we aimed to characterise the population of e-cyclists in German-speaking Switzerland and to investigate which factors (e.g. gender) are associated with the risk of a single-vehicle crash.

2. Methods

2.1. Recruitment of study participants

Between September and November 2016, we conducted a survey among e-cyclists in German-speaking Switzerland. We included riders of the two e-bike types available in Switzerland: e-bikes with a pedal support up to 45 km/h (in the following referred to as "e-bikes45") and e-bikes with a pedal support up to 25 km/h ("e-bikes25"). Both types of

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e-bikes usually cannot be ridden by electric motor alone and require pedalling. We aimed to obtain a sample of e-cyclists as representative as possible. Unfortunately, there is no registry containing all owners of e-bikes in Switzerland. Only owners of e-bikes45 are registered at their respective cantonal licencing departments. Of those, six provided addresses of e-bike45 owners. In addition, addresses of participants of e-bike training courses from 3 providers were available. Letters were sent to 484 addresses of participants of e-bike training courses and 2400 addresses of registered owners of e-bikes45 (active recruitment). Moreover, to reach as many e-cyclists as possible, multiple channels (e.g. website, newsletter, social media) of the Swiss Council for Accident Prevention and several other (partner) organisations were used (passive recruitment). The passively recruited participants and the registered owners of e-bikes45 took part online, and the participants of the e-bike training courses were given the option to participate online or via written questionnaire. The main focus of the study (single-vehicle crashes) was not actively disclosed in the recruitment process. As an incentive, there was a drawing among study participants for an e-bike and 10 vouchers of two (e-)bike shops with a value of 50 and 100 Swiss Francs, respectively.

2.2. Questionnaire

The written and online questionnaire consisted of three parts. The first part contained general questions related to the e-bike use (e.g. frequency of use). At the end of the first part of the questionnaire, participants were asked if they had ever experienced a single-vehicle accident in road traffic. For those who had, detailed questions regarding the mechanisms and causes of the crash and the injury were asked. Regarding the latter, four categories were used (no injury, minor (self-treatment), moderate (outpatient treatment, e.g. in a doctor's practice) and serious injury (requiring inpatient treatment in a hospital). The remaining participants answered questions about various safety aspects relating to e-bikes instead (not part of this paper). Part 3 of the questionnaire consisted of demographic questions (e.g. age, gender).

2.3. Data analyses

For the final analyses, the following exclusion criteria were defined: incomplete or double participation, false statement about having been involved in a single-vehicle accident (which resulted in the wrong questions being answered), riders of cargo e-bikes, participants under the age of 14 years, and observations with too many missing values, completely inconsistent answers or missing weighting factor (see next paragraph). In the first part of the results section, we present analyses in which we aimed to characterise active e-cyclists in German-speaking Switzerland and their risk of a single-vehicle crash in road traffic. Inactive (participants who had stopped riding an e-bike) or irregular e-cyclists (participants who used an e-bike not more than a few times per year) were excluded from these two analyses (sample A). Analyses of mechanisms and causes of single-vehicle crashes were based on all e-cyclists with accident experience regardless of whether or not they still (regularly) rode an e-bike at the time of the survey (sample B).

Due to the active recruitment, riders of e-bikes45 and e-cyclists who had attended an e-bike training course were overrepresented in the sample. In order for the sample to be as representative as possible for e-cyclists in German-speaking Switzerland, we conducted weighted analyses. The weighting factors (for e-bike type and training course participation) were derived from the passively recruited sample, which was considered representative. For sample A, the weighting factor ranged from 0.2 to 1.6. For sample B, it ranged from 0.6 to 1.3.

Participants who had experienced a single-vehicle accident could specify the accident mechanism(s) in a closed-ended (multiple choice) and open-ended (optional accident description in their own words) type of question. Two researchers independently checked the consistency of the two answers. For some participants, the accident description did not correspond to the category chosen in the closed-ended question. In these cases, only if the two researchers agreed, the responses in the closed-ended question were changed. Based on the accident descriptions, four additional accident mechanisms were identified that were previously not included in the questionnaire. As for accident causes, the participants were asked to indicate on a 4-point Likert scale (no, slight, medium, strong influence) to what extent several predefined causes contributed to the crash. For the analyses in this paper, the answers were dichotomised (no influence vs. at least a slight influence).

Logistic regression models were calculated for single-vehicle crash risk (yes/no) and injury severity (no/minor vs. moderate/serious injury). The approach was the same for all logistic analyses: In a first step, all factors potentially linked to the outcome were tested in binary models. The factors for which at least one value was associated with the outcome with a p-value of 0.2 or less were included in a multivariable regression model. The variables with the highest p-values in this model were then eliminated stepwise until only variables with a p-value of 0.2 (for at least one value) or less were left in the model.

An index representing e-bike riding exposure was calculated using duration of e-bike use and riding frequency. The resulting index ranged from 1.4 to 6.9. The participants were also asked about their feeling of safety in 5 potentially challenging situations: riding the e-bike 1) with high speed (> 30 km/h), 2) on a street with heavy traffic, 3) on non-paved roads, 4) single-handedly, and 5) on very steep streets (up- and downhill)) with values reaching from 1 (I do not feel safe in this situation) to 5 (I feel very safe in this situation). A new variable representing the general feeling of safety when riding an e-bike was built taking the mean value of the answers to these 5 questions.

All statistical analysis were carried out using IBM SPSS 24.0 (IBM Corp, Armonk, NY, USA) and STATA version 14.0 (StataCorp., College Station, TX, USA).

3. Results

3.1. Characteristics of the study participants

In total, 4044 participants completed the questionnaire. Of those, 386 were excluded from analyses mostly (78%) because they had stopped e-cycling or only irregularly rode an e-bike (less than several times a year). The final sample consisted of 3658 (still active and regular) e-cyclists. The characteristics of sample A are shown in Table 1. Mean age was 54.4 years (s.d. = 12.8). 32% rode an e-bike45 and 68% an e-bike25. Riders of e-bikes45 were mainly male and young: 60% of e-cyclists riding e-bikes45 were men, 40% were women. 7% of e-bike45 riders were aged between 14 and 34 years, 37% between 35 and 49 years, 45% between 50 and 64 years and 11% were 65 and older. The large majority of e-bike riders rode an e-bike with a neutral weight distribution (rear-wheel motor with battery in the frame or mid-mounted motor). Most participants have had experience in riding a two-wheeler (bicycle, moped or motorcycle) before the beginning of their e-bike use (77% at least several times a month) and had ridden an e-bike for more than 2 years (64%). At the time of the survey, 47% and 10% still regularly rode a bicycle and moped/motorcycle, respectively. While in the warmer months of the year (spring/summer/fall), 77% rode their e-bike at least several times a week, in winter this percentage dropped to 35%. About one third (34%) of the participants had already experienced an accident with their e-bike (collision with another road user and/or a single-vehicle accident in road traffic or offroad). Single-vehicle crashes in road traffic were the most common crash type: every sixth (17%) of the participants reported such a crash. This percentage was stable throughout all age groups. 8% of the participants had experienced a collision with another road user.

3.2. Crash risk

In order to identify factors relevant to the risk of having experienced