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Article

Characteristics of Commuters' Single-Bicycle Crashes in Insurance Data

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Abstract: In order to maximize the public health benefits of cycling, the negative impacts of cycling, such as the number and types of crashes, should be identified. Single-bicycle crashes, in which other road users are not collided with, are one of the main safety concerns in cycling, but comprehensive knowledge on these crashes is not available due to poor data sources. This study aimed to identify characteristics of commuters' single-bicycle crashes in Finland. Firstly, insurance data covering 9268 commuter bicycle crashes in 2016 and 2017 were analyzed to find single-bicycle crashes. The insurance data are based on self-reported crashes. In total, 3448 single-bicycle crashes were found with crash descriptions that were informative enough for investigation of their characteristics. According to the results, 62.9% (95% confidence interval +/− 1.6%) of the crashes were related to the infrastructure. In the majority of infrastructure-related crashes, the road surface was slippery. The slippery road surface was typically due to icy or snowy conditions. The lack of proper data complicates the recognition of single-bicycle crashes, and hence policy actions and research projects are needed to develop better data sources for proper investigation of cycling safety.

Keywords: single-bicycle crash; cycling; safety; crash data; commuter

1. Introduction

Policy actions and recent national strategies for cycling aim to increase the modal share of cycling in many countries, such as in Austria (Federal Ministry of Agriculture, Forestry, Environment and Water Management, Cycling Master Plan 2015-2025, Vienna, Austria, 2015), Finland (Finnish Ministry of Transport and Communications, National Strategy for Walking and Cycling 2020, Programmes and Strategies April 2011, Helsinki, Finland), and Norway (Norwegian Ministry of Transportation and Communications, National Transport Plan 2014-2023, Oslo, Norway, 2012). The public health benefits of cycling, which have been identified in many studies [1,2], entail one of the most important arguments to promote cycling. In countries where cycling is a popular mode of transport, the share of cycling crashes may also be significant, which diminishes the health benefits of cycling. In the Netherlands, where cycling is a popular transportation mode, about two-thirds of serious traffic injuries are injuries to cyclists [3]. An increase in the modal share of cycling is desirable, but at the same time negative impacts (such as crashes) should be acknowledged and reduced. Even though public health should be promoted, the consequences of crashes diminish individuals' quality of life temporarily or even permanently. In order to promote cycling safety, not only the number of crashes but also the causes of the crashes should be known.

A main obstacle to gathering information on bicycle crashes is the lack of data [4]. Official crash statistics, which are typically based on police data, include all or almost all fatal traffic crashes in EU countries [5], but the statistics exclude a major part of the crashes with serious or minor injuries, because the police are not always informed of these cases [6]. The share of bicycle crashes is typically larger in serious injuries than in fatalities [7], and hence cases other than fatal crashes should also be considered when safety actions are determined. In Finland, in 2014–2017, 11% of fatalities and 30% of those seriously injured (MAIS 3+) were cyclists [8]. Of the annual 267 seriously injured cyclists, 19% are reported to the police and 81% are solely recorded in hospital data [8]. Because the hospital record does not include data on crash characteristics (such as crash types), the majority of the characteristics of bicycle crashes are unknown. It is possible that actions to promote cycling safety are planned based on the circumstances of fatal crashes, because the causes and related factors of the fatal crashes are known, albeit the crashes with less severe outcomes and with potentially different causes could also cause great losses to public health. Other data sources, such as insurance data, are necessary to complement deficiencies in police and hospital data. Policy actions are needed to enhance registration of cyclists' injurious crashes.

Single-bicycle crashes may be the most unknown crash type, as the police are not typically informed of these cases. Single-bicycle crashes have been identified as a major concern within bicycle crashes in Finland [9] and in other countries [10,11]. This study aimed to identify the main characteristics of commuters' single-bicycle crashes in Finland. In single-bicycle crashes, other road users are not involved.

Previously, characteristics and causes of single-bicycle crashes have been studied in Sweden, the Netherlands, and Australia. Niska and Eriksson [12] used the Swedish traffic accident database (STRADA), in which police and hospital records are linked, to analyze the types of the single-bicycle crashes with serious injuries. In the study, 4000 single-bicycle crashes from years between 2007 and 2012 were selected, of which 2848 included the cause of the crash. Schepers and Klein Wolt [13] sent a questionnaire to 2975 patients in several Dutch hospitals who were recently involved in a cycling crash. In the questionnaire, there were questions to categorize the crash (e.g., crash type and related factors). In total, 669 single-bicycle crashes were identified. The study by Beck et al. [14] presents characteristics of 62 single-bicycle crashes in Melbourne, Australia. The study is based on interviews with injured cyclists. The interviews were conducted in two hospitals in 2013.

Compared to the previous studies, this study gives an outlook on the main characteristics of single-bicycle crashes in a northern country in which snowy and icy conditions last several months a year, which is different from the Netherlands and Australia. Sweden and Finland are situated close together, and hence the results from these countries are more comparable in the terms of climatic conditions.

2. Materials and Methods

2.1. Data on Bicycle Crashes

The data from the Finnish Workers' Compensation Center (TVK) were used to analyze single-bicycle crashes in Finland in 2016-2017. TVK [15] coordinates the practical application of workers' compensation. TVK also compiles statistics on occupational diseases and accidents at work, including accidents on a journey to or from work. In Finland, employers are obliged to insure their employees against work-related accidents. The analyzed data include crashes that have occurred on a journey from home to work or vice versa, and for which the insurance company has paid compensation from the occupational accident insurance. This dataset was selected because other crash records (e.g., hospital data) do not include crash descriptions for the evaluation of main characteristics or the amount of single-bicycle crashes is minor (e.g., police data and data on in-depth investigated crashes). The insurance data from TVK is based on self-reported crashes. The cases have been handled by the insurance companies, which have paid the compensation. Crash descriptions in the data were written by the injured cyclist, the supervisor, another employee, or the claims handler in the insurance company. In this study, a single-bicycle crash is determined as a crash in which a cyclist is injured during cycling, during (dis)mounting from a bicycle, or due to a fall, with no physical contact with other road users occurring. The data also include crashes which may not be included in the official road traffic accident statistics (e.g., crashes that occurred on the workplace's private premises or on unpaved paths in woods). Overall, the majority of the crashes are not included in the official statistics because the police are not typically informed of single-bicycle crashes.

Before the analysis of the characteristics, the determined single-bicycle crashes were selected from the dataset, which also includes other crash types. Firstly, potential single-bicycle crashes were searched in the whole dataset, including 9268 injured cyclists in 2016–2017, by using three variables for the crash type in the search: (1) fall, slip, or trip; (2) fall on an object; and (3) driving off the road. Other variables ((4) collision with a car, (5) collision with a moped or a motorcycle, (6) collision with a tram or a train, (7) violence, and (8) other crashes) were not included because they do not indicate single-bicycle crashes. In total, 7627 cycling crashes were coded for these three variables. For instance, the cases in which a cyclist collided with another road user were filtered. However, 1350 of 7627 crashes did not include crash descriptions. These cases were filtered from the final data because the characteristics of these crashes cannot be evaluated without the descriptions. Secondly, crash descriptions (1–3 sentences) of each of the remaining 6277 (7627 − 1350) crashes were analyzed to ensure that each case fulfilled the definition of being a single-bicycle crash. In total, 301 of 6277 crashes were filtered because these were not single-bicycle crashes according to the descriptions. For instance, the cases were excluded if a fall occurred while walking a bicycle (e.g., a pedestrian crash) or there was physical contact with another road user. The aforementioned cases should have been filtered when the data were selected by using variables in the first place, but due to mistakes in recording of the crashes, some cases were not filtered until this phase. Because mistakes in the recording of the crashes are possible, the crash descriptions take priority over the variables. Thirdly, the characteristics of the crashes were determined by analyzing the crash descriptions. In 2528 of the remaining 5976 (6277 − 301) crashes, it was not possible to determine the characteristics by analyzing the description because the description was not informative enough. As an example, a description such as "he fell with a bicycle on the journey from work to home" is insufficient. The main characteristic of the crash cannot be determined according to a description of this kind. Finally, 3448 (5976 − 2528) single-bicycle crashes included the main characteristic of the crash and were recognized and included in this study (Figure 1). Of the 3448 crashes, (1) 3212 were caused by falls, slips, or trips, (2) 12 were caused by falls on an object, and (3) 224 involved driving off the road. In addition to the descriptions, the number of sick leave days and the injured body part were used in the analysis.

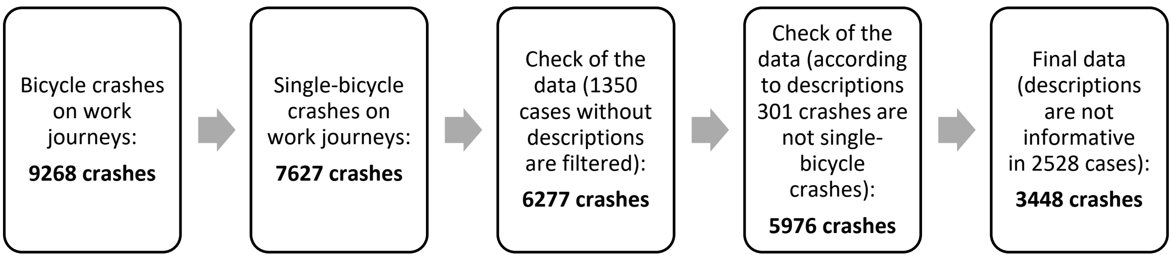

Figure 1. Stages in the formation of the data of single-bicycle crashes.

2.2. *Classification of the Single-Bicycle Crashes*

A classification of single-bicycle crashes was developed by reviewing categorization systems presented in previous studies and by considering the characteristics of Finnish data (Appendix A Table A1). Schepers and Klein Wolt [13] utilized direct causes (a cause or an incident instantly prior to a crash), which were mainly related to the infrastructure, the cyclist, and the bicycle. In addition, latent factors (e.g., system-related factors or an intoxicated cyclist) were recognized, but these were not utilized in the study by Schepers and Klein Wolt [13]. One characteristic of the crash was selected in most of the cases, but some of the crashes included two or three factors. Niska and Eriksson [12] used a somewhat similar system, except that they had some variables related to the latent factors (e.g., under the influence of alcohol and cycling from a party). One to three causes were selected for each crash.

Some latent factors (e.g., secondary activity) were recognized in Finnish data, but crash descriptions mainly indicated direct factors, which were also used in the previous studies.

Due to the characteristics in the Finnish data and dissimilarities in the reference studies, the categorization could not be completed, similarly to in Sweden and the Netherlands. For this study, the characteristics of the crashes were divided into five main groups (Table A1): (1) infrastructure, (2) cyclist-related, (3) bicycle malfunction, (4) interaction with other road user, and (5) other. In Sweden, two separate groups (operation and maintenance, and road design) were related to the infrastructure. These groups were combined into one main group (infrastructure) in this study because it was not always possible to determine whether the characteristic was related to maintenance or road design. In the Netherlands, interaction with other road users was included in the cyclist-related crashes. In this study, these cases are separate main groups, as in Sweden, because the interaction with others was evaluated to be a typical characteristic of the crash.

Overall, as many subgroups and the most detailed descriptive factors possible were utilized in the categorization of Finnish data. For instance, skidding due to a slippery road surface (1a) was divided into seven descriptive factors, because the cause of the slippery road surface (e.g., ice/snow or gravel) may be diverse. In all cases, similar subgroups and descriptive factors could not be used compared to Sweden, in which several subgroups were used. For instance, riding off the road (1d) is not recognized as a cause in the Finnish data. Riding off the road occurred in some cases, but some other factor was recognized as the main characteristic (e.g., avoidance of other road user) that caused the cyclist to ride off the road. In addition, the effect of low or high speed (2b) was not usually possible to evaluate from the description. Instead, cases where the cyclists suffered an attack of illness (2i) are included in this study, albeit this is not a subgroup in the reference studies.

In the analysis, one main characteristic, which was the starting point of the crash, was selected for each crash. In some cases, avoidance of other road users was the starting point of a fall crash, but the road surface was also slippery (e.g., icy). In these crashes, the evasive action (4a) was selected as the main characteristic, because the crashes would not likely have occurred without the action. However, a slippery road surface may have had an impact on the crash as a secondary factor. Slippery road surface cases as secondary factors are also discussed. In some cases, due to a slippery road surface (1a), it was not possible to determine the cause of the slipperiness. Although it is known that the date of a particular crash was in winter, it is not assumed that the cause of the slipperiness was ice or snow. These crashes were coded as unknown/winter or unknown/summer depending on the date. Some examples of how different crash descriptions were categorized into subgroups and descriptive factors are presented in Table 1.

Table 1. Examples of the categorization of crashes into different subgroups and descriptive factors.

Crash Description	Subgroup and Descriptive Factor	Commentary
Gravel on the asphalt skidded under the wheel of a bicycle and the cyclist fell.	1a. Skidding due to a slippery road surface (gravel)	The cyclist lost their balance due to gravel on the road.
The cyclist skidded because the surface of the cycle path was icy. The cycle path was not gritted.	1a. Skidding due to a slippery road surface (ice/snow)	The cyclist lost their balance due to slipperiness.
The front wheel of the bicycle collided with a curb and the cyclist fell.	1c. Colliding with a curb	The cyclist fell due to a collision with a curb.
The cyclist dismounted from the bicycle and a foot slipped from a pedal. The cyclist fell.	2d. (Dis)mounting	The cyclist fell during dismounting.
An oncoming passenger car turned in front of the cyclist to go to a parking area. The cyclist braked to avoid a collision and fell over the handlebars.	4a. Avoidance of other road user (a motor vehicle)	The avoidance of a car was the cause for the braking maneuver.
The cyclist started turning, while another cyclist approaching behind started overtaking the cyclist in front. The cyclist in front made an evasive action to avoid a collision and fell.	4a. Avoidance of other road user (a cyclist)	The cyclist lost balance and fell due to an evasive action.

3. Results

Commuters' single-bicycle crashes were typically related to infrastructure (62.9%, 95% confidence interval (CI) +/− 1.6%). In particular, skidding due to a slippery road surface (47.0%, 95% CI +/− 1.7%) was a typical characteristic related to infrastructure (Table 2). A slippery road surface was usually caused by ice or snow. A cyclist-related crash was recognized in 15.8% (95% CI +/− 1.2%) of cases and an interaction situation with other road users was recognized in 15.5% (95% CI +/− 1.2%).

Table 2. The number and shares of main characteristics of commuters' single-bicycle crashes with upper and lower 95% confidence interval (CI).

1. Infrastructure (n = 2 170, 62.9% +/− 1.6%)
1a. Skidding due to a slippery road surface (n = 1622, 47.0% +/− 1.7%)
-Ice/snow (n = 1044, 30.3% +/− 1.5%)
-Gravel (n = 178, 5.2% +/− 0.7%)
-Leaves (n = 22, 0.6% +/− 0.3%)
-Clay (n = 4, 0.1% +/− 0.1%)
-Gravel road (n = 47, 1.4% +/− 0.4%)
-Unknown/winter (November-March) (n = 183, 5.3% +/− 0.7%)
-Unknown/summer (April-October) (n = 144, 4.2% +/− 0.7%)
1b. Colliding with an object, e.g., a bollard (n = 150, 4.4% +/− 0.7%)
1c. Colliding with a curb (n = 144, 4.2% +/− 0.7%)
1d. Riding off the road or edge of road (n = 0, 0%)
1e. Loss of control due to an uneven road surface, e.g., a pothole (n = 149, 4.3% +/− 0.7%)
1f. Driven against rail (n = 105, 3.0% +/− 0.6%)
-Tram rails (n = 96, 2.8% +/− 0.5%)
-Railway rails (n = 9, 0.3% +/− 0.2%)
2. Cyclist-related (n = 546, 15.8% +/− 1.2%)
2a. Braking mistakes (n=163, 4.7% +/− 0.7%)
2b. Low/high speed (n = 0, 0%)
2c. Baggage, e.g., hit the front wheel (n = 51, 1.5% +/− 0.4%)
2d. (Dis)mounting (n = 137, 4.0% +/− 0.7%)
2e. Stunting (n = 0, 0%)
2f. Handling fault (n = 81, 2.3% +/− 0.5%)
2g. A foot slipped off a pedal (n = 73, 2.1% +/− 0.5%)
2h. Distraction (n = 35, 1.0% +/− 0.3%)
-A mobile phone (n = 4, 0.1% +/− 0.1%)
-A secondary activity (n = 20, 0.6% +/− 0.3%)
-Looking back (n = 11, 0.3% +/− 0.2%)
2i. Attack of illness (n = 6, 0.2% +/− 0.1%)
3. Bicycle malfunction (n = 178, 5.2% +/− 0.7%)
3a. Bicycle malfunction (n = 178, 5.2% +/− 0.7%)
-Chain broke or came off (n = 71, 2.1% +/− 0.5%)
-Other malfunction (n = 107, 3.1% +/− 0.6%)
4. Interaction with other road user (n = 534, 15.5% +/− 1.2%)
4a. Avoidance of other road users (n = 493, 14.3% +/− 1.2%)
-A motor vehicle, e.g., a car (n = 216, 6.3% +/− 0.8%)
-A cyclist (n = 146, 4.2% +/− 0.7%)
-A pedestrian (n = 131, 3.8% +/− 0.6%)
4b. Avoidance of an animal (n = 41, 1.2% +/− 0.4%)
-A dog (n = 26, 0.8% +/− 0.3%)
-Other animal (n = 15, 0.4% +/− 0.2%)
5. Other (n = 20, 0.6% +/− 0.3%)
5a. Other or unknown (n = 20, 0.6% +/− 0.3%)
-Windy weather (n = 5, 0.1% +/− 0.1%)
-Colliding with a ball/children playing (n = 3, 0.1% +/− 0.1%)
-A disability while cycling (n = 12, 0.3% +/− 0.2%)
Total (n = 3448, 100%)

In 39 of 493 crashes, due to the avoidance of other road users (4a), the road surface was also slippery (e.g., ice/snow). These 39 crashes with a slippery road surface are not included in the skidding cases (1a) because the evasive action was evaluated as the main factor of the crash. The skidding was identified as a secondary factor in these crashes. Cases in which skidding due to a slippery road surface (1a) was the main factor and which also included braking maneuvers or were situated at a curve are coded as 1a cases. The braking maneuver or the curve was recognized in 358 of 1622 crashes, in which the road surface was slippery. In the crashes, in which braking mistakes (2a) was the main characteristic, other factors (e.g., slippery road surface) were not identified.

In winter months (October–March), 81% of the crashes were related to infrastructure. In the summer months (April–September), the same factor was responsible for 44% of crashes (Figure 2). In the summer months, cases involving a cyclist, a bicycle, and an interaction were emphasized compared to the winter months. The crash risk (crashes/million km by bicycle) is larger between December and February (312) compared to between September and November (146), March and May (102), or June and August (76). The number of kilometers travelled by bicycle is based on all cycling journeys in Finland. The number of crashes is based on crashes on work journeys.

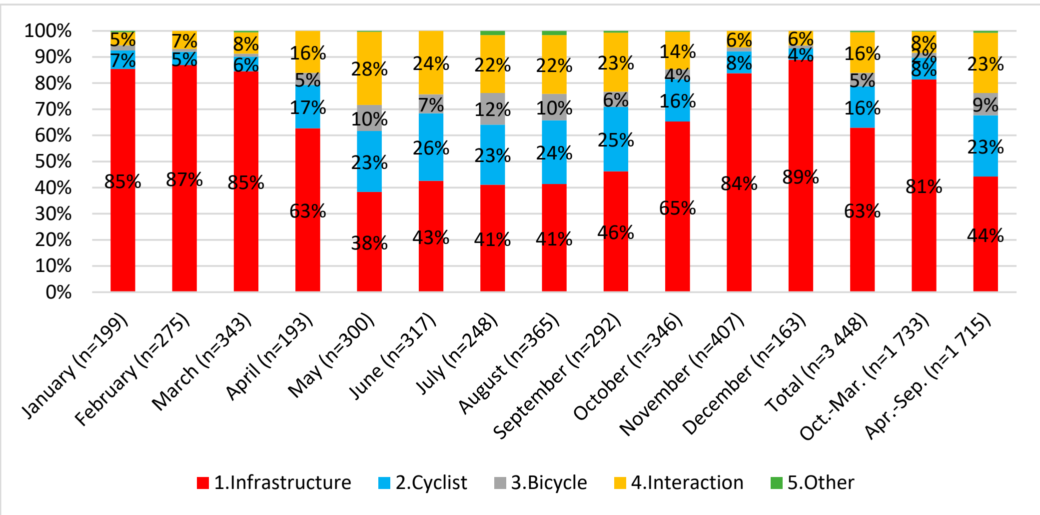

Figure 2. The number of crashes and the share of the main characteristics in each month.

Two-thirds of the reported crashes resulted in an incapacity for work of less than four days. However, 9% of the injuries resulted in an incapacity for work of more than 30 days (Table 3). In the data, the number of cases resulting in an incapacity for work of zero days is not available, and hence the first group is 0-3 days in Table 3. Of the different main characteristics, 66% of infrastructure-related crashes resulted in 0–3 days of incapacity for work and 63% of cyclist-related crashes resulted in 0–3 days of incapacity for work (Appendix A Table A2). Injuries of the upper (29%) or lower limbs (29%) were the most typical injuries (Table 4).

Table 3. The numbers and shares of days of incapacity for work.

Incapacity for Work	
Fatal	0 (0%)
181 days or more	24 (1%)
91–180 days	59 (2%)
31–90 days	231 (7%)
15–30 days	212 (6%)
7–14 days	324 (9%)
4–6 days	332 (10%)
0–3 days	2 266 (66%)
Total	3 448 (100%)

Table 4. The numbers and shares of injuries to different body parts.

Body Part with an Injury	
Head	236 (7%)
Neck	44 (1%)
Back	92 (3%)
Body and viscera	293 (8%)
Upper limbs	988 (29%)
Lower limbs	984 (29%)
Several body parts	736 (21%)
Other/unknown	75 (2%)
Total	3448 (100%)

4. Discussion

According to the insurance data, skidding due to a slippery road surface is the most common characteristic of commuter single-bicycle crashes in Finland. It seems that winter maintenance of cycle paths (e.g., sweeping and salting a path) should be enhanced, because slippery road surfaces were typically due to icy or snowy conditions. In addition, the cyclists should take the conditions into account, which could mean slowing down their speed. However, proper recommendations on the measures cannot be made because the data are not based on in-depth investigations and the causes of crashes cannot be identified. Infrastructure-related crashes are also common in other countries, as 59% of single-bicycle crashes in Sweden (n = 2848) and 58% in the Netherlands (n = 669) are related to the infrastructure [12,13]. The corresponding share is 63% in this study (n = 3448). Skidding due to a slippery road surface was also the most typical case among the infrastructure-related crashes in Sweden and the Netherlands. Crashes related to a cyclist were more common in Sweden and the Netherlands than in this study. Compared to other previous studies with smaller samples (Beck et al. [14] (n = 62); Public Health Agency of Canada [16] (n = 266)), loss of control cases, including skidding due to a slippery road surface, were also the most common crashes in Australia (37%) and Canada (29%). In Canada, doing stunts or distractions (25%) were the second most common case, which is a difference to this study, in which there were only a few distraction cases. Colliding with an object or striking a pothole (13% in Australia, 10% in Canada) were almost as typical as in Finland (13%).

An error in the interaction with another road user was recognized in 16% of the crashes. These cases include encounters with motor vehicles, pedestrians, and cyclists. In the encounters with a motor vehicle, the vehicle was typically a passenger car. In 2014-2016, 59% (on average 16 cases annually) of the fatal crashes with cyclists occurred in collisions with a motor vehicle in Finland [17]. The number and related factors of fatal crashes with cyclists are well known, because since 2001, the investigations of fatal road crashes have been mandated by law in Finland [18]. However, the data on the fatal crashes may not be enough for the planning of countermeasures because the number of fatal crashes is relatively small. Understanding the mechanics and related factors of the avoidance cases and other conflicts between cyclists and drivers is important because these cases are more common than collisions. It is possible that the conflicts could appear as collisions in other circumstances if a small detail was different. This study provides an outlook on the characteristics of encounters without a collision. However, encounters between cyclists and drivers should be studied further in order to implement necessary countermeasures to avoid an increase in the number of crashes if cycling becomes more popular. Policy actions and research projects are needed to develop linkages between different data sources (e.g., hospital, police, and insurance data) for proper investigations of avoidance cases and conflicts. Different data sources are already being used to study cycling crashes, but investigation of single-bicycle crashes requires more work. For instance, information on the severity of injuries in police data is provided by hospital data. However, single-bicycle crashes are not typically reported to the police, and hence police data do not provide information on these crashes, although data on the injuries caused by single-bicycle crashes are available in hospital data. The hospital data do not include other characteristics of the crashes.

Braking maneuvers were identified in 5% of the cases, but braking was also involved in many other crashes (e.g., avoidance of other road users). In many crashes with braking maneuvers, the cyclist fell over the handlebar, which was typically caused by a force on the front wheel brake. A technical solution could be developed to balance braking situations (e.g., the maximum force of front brakes could be restricted). In addition, 4% of the cases were related to (dis)mounting. With minor structural changes to a bicycle, the safety for—in particular—women and older cyclists could be improved during (dis)mounting [19].

In the different seasons and months, most of the crashes occurred in autumn and November. However, the modal share of cycling is lower in autumn than in summer in Finland [20]. The smaller number of crashes in the summertime may be a consequence of the fact that many people have holidays in the summer, thus they cannot get injured on a work journey. Consequently, potential cycling injuries during the holiday are not recorded as commuter crashes. In this study, summer months may appear safer than in the analysis, in which crashes from all types of cycling journeys are included. The crash risk is clearly the highest in the winter, as the risk is more than doubled in winter compared to autumn, in which the most crashes occur. Although the number of crashes is the lowest in winter, the number of cycled kilometers is three to six times lower in winter than in other seasons [20], which has an impact on the high crash risk. It should be noted that crash risk is based on commuters' crashes, but all cycling journeys are considered in the crash risk. This may have an impact on the crash risk comparison between different seasons, because the share of work journeys by a bicycle is likely larger in winter than in summer. A slippery road surface as a characteristic in 81% of the crashes in winter emphasizes the role of icy and snowy conditions in single-bicycle crashes. In the summer months, the number of crashes related to a cyclist, a bicycle, and an interaction is clearly higher than in the winter months.

There are some restrictions in this study. It was not possible to evaluate the main characteristics of the single-bicycle crashes in each case due to deficient descriptions or a lack of description. If it had been possible to evaluate each crash, the results may have been different. In addition, 1641 cases that included variables 4-9, which were not analyzed, may also include some single-bicycle crashes, although these variables indicate other crash types than single-bicycle crashes. The number of single-bicycle crashes with proper descriptions is likely minor among the crashes that include variables 4-9; hence, the impact of these crashes would likely be small in the results. In total, it was possible to evaluate the characteristics in 3448 crashes, which is a relatively large number of cases. In the analyzed data, the crash description was based on the opinion of the cyclist. It should be noted that in some cases, the cyclist may have not reported all the important factors related to the crash, which may have had an impact on the results of this study. It should also be noted that other researchers could evaluate the crashes in a different way, which may have had an impact on the results and the comparison with other studies. In further studies, it is recommended to also utilize other insurance data than the data from work journeys. For instance, data for crashes, which are compensated by voluntary accident insurance, would enable us to investigate cases that occur during other types of journeys (e.g., casual journeys).

5. Conclusions

The safety of vulnerable road users—in particular cyclists—is one of most important topics in traffic safety. Insurance data, which are based on commuters' crashes in this study, are a valuable data source to research the characteristics of single-bicycle crashes, because knowledge on these crashes is deficient in Finland and worldwide. In Finland, road traffic accident statistics in 2014–2017, in which hospital and police data were combined, include an average of 267 seriously injured and 697 slightly injured cyclists annually [8]. The number of cases contained in insurance data and only related to single-bicycle crashes is higher compared to these numbers. It is recommended that public authorities and traffic safety experts also utilize data sources other than official crash statistics to study cycling safety.

The analysis indicates potential factors to be taken into account in future cycling safety work and policy actions. Although the data analyzed in this study enable better understanding of the characteristics of single-bicycle crashes, the crashes should be studied further before implementing specific countermeasures, because the data are not based on in-depth investigations and they only relate to commuters' injuries. According to the analysis, it seems that winter maintenance and the quality of the cycling infrastructure should be enhanced to prevent crashes related to slippery road surfaces (such as ice or snow). In addition, the anticipatory behavior of cyclists, the behavior of cyclists and other road users in the encounters, and the structure of a bicycle seem to be potential factors that should be focused on based on the analyzed data.

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Appendix A

Table A1. The combined categorization system for single-bicycle crashes (first column), which is used in this study and which was developed based on the studies of Schepers and Klein Wolt [13] and Niska and Eriksson [12], along with the characteristics contained in Finnish data. Columns 2-4 present whether the specific study includes the subgroup (yes or no) and whether the subgroup includes more detailed descriptive factors, which are presented in parentheses (e.g., 1a: ice/snow). Some subgroups in the reference studies may be a combination of two subgroups. For instance, in the study of Schepers and Klein Wolt [13], 1a includes 1f.

The Combination of Categorization System	Is a Subgroup Included? (Descriptive Factors of the Subgroups are Presented in Parentheses)		
	Schepers and Klein Wolt [13]	Niska and Eriksson [12]	This Study
1. Infrastructure			
1a. Skidding due to slippery road surface	Yes, includes 1f.	Yes (ice/snow, gravel, leaves, clay, gravel road, other/unknown, bend/curve)	Yes (ice/snow, gravel, leaves, clay, gravel road, unknown/winter, unknown/summer)
1b. Colliding with an object, e.g., a bollard or a stone	Yes	Yes (fixed object, temporary object)	Yes (loss of control due to avoidance of an object is included)
1c. Colliding with a curb	Yes in 1d.	Yes	Yes, includes skidding on a curb
1d. Riding off the road or edge of road	Yes, includes 1c.	Yes	No
1e. Loss of control due to an uneven road surface, e.g., a pothole	Yes	Yes	Yes
1f. Driven against rail	Yes in 1a.	Yes	Yes (tram rails, railway rails)
2. Cyclist-related			
2a. Braking mistakes	Yes	Yes	Yes
2b. Low speed	Yes, includes 2d	Yes (low speed, high speed)	No
2c. Baggage, e.g., hit the front wheel	Yes, includes 2g	Yes	Yes
2d. (Dis)mounting	Yes in 2b.	Yes	Yes
2e. Stunting	Yes	Yes	Yes
2f. Handling fault	Yes in 4a.	Yes, includes 2g.	Yes, includes loss of balance and stumbling
2g. Foot slipped off a pedal	Yes in 2c.	Yes in 2f.	Yes
2h. Distraction	No	Yes (mobile phone, secondary activity, alcohol, cycling from party)	Yes (mobile phone, secondary activity, looking back)
2i. Attack of illness	No	No	Yes

Table A1. *Cont.*

The Combination of Categorization System	Is a Subgroup Included? (Descriptive Factors of the Subgroups are Presented in Parentheses)		
	Schepers and Klein Wolt [13]	Niska and Eriksson [12]	This Study
3. Bicycle malfunction			
3a. Bicycle malfunction	Yes	Yes	Yes (chain broke or came off, other malfunction)
4. Interaction with other road user			
4a. Avoidance of other road users	Yes, includes 2f.	Yes (other road user, dazzled by vehicle lights)	Yes (motor vehicle, cyclist, pedestrian)
4b. Avoidance of animal	Yes in 5a.	Yes (own dog, some other pet)	Yes (dog, some other pet)
5. Other			
5a. Other or unknown	Yes, includes 4b.	Yes (windy weather, cycling uphill/downhill, dazzled by sun, dark conditions)	Yes (windy weather, colliding with a ball/children playing, disability while cycling)

Table A2. The amount of days of incapacity for work and the characteristics of the crashes.

The Characteristics of the Crashes	Incapacity for Work			
	0-3 Days	4-30 Days	31 Days or More	Total
1. Infrastructure	**1440 (66%)**	**528 (24%)**	**202 (9%)**	**2170 (100%)**
1a. Skidding due to slippery road surface	1075 (66%)	392 (24%)	155 (10%)	1622 (100%)
1b. Colliding with an object	97 (65%)	42 (28%)	11 (7%)	150 (100%)
1c. Colliding with a curb	97 (67%)	32 (22%)	15 (10%)	144 (100%)
1d. Riding off the road or edge of road	0	0	0	0
1e. Loss of control due to an uneven road surface	100 (67%)	35 (23%)	14 (9%)	149 (100%)
1f. Driven against rail	71 (68%)	27 (26%)	7 (7%)	105 (100%)
2. Cyclist-related	**346 (63%)**	**156 (29%)**	**45 (8%)**	**547 (100%)**
2a. Braking mistakes	107 (66%)	45 (28%)	11 (7%)	163 (100%)
2b. Low speed	0	0	0	0
2c. Baggage	34 (67%)	14 (27%)	3 (6%)	51 (100%)
2d. (Dis)mounting	78 (57%)	44 (32%)	15 (11%)	137 (100%)
2e. Stunting	0	0	0	0
2f. Handling fault	51 (63%)	22 (27%)	8 (10%)	81 (100%)
2g. Foot slipped off a pedal	49 (67%)	19 (26%)	5 (7%)	73 (100%)
2h. Distraction	23 (66%)	10 (29%)	2 (6%)	35 (100%)
2i. Attack of illness	4 (67%)	1 (17%)	1 (17%)	6 (100%)
3. Bicycle malfunction	**116 (65%)**	**50 (28%)**	**12 (7%)**	**178 (100%)**
4. Interaction with other road user	**350 (66%)**	**130 (24%)**	**54 (10%)**	**534 (100%)**
4a. Avoidance of other road users	327 (66%)	117 (24%)	49 (10%)	493 (100%)
4b. Avoidance of animal	23 (56%)	13 (32%)	5 (12%)	41 (100%)
5. Other	**14 (70%)**	**5 (25%)**	**1 (5%)**	**20 (100%)**
Total	**2266 (66%)**	**868 (25%)**	**314 (9%)**	**3448 (100%)**

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