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Crowdsourced bicycling crashes and near misses: trends in Canadian cities

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ABSTRACT

Safety concerns are a barrier to increasing bicycling. BikeMaps.org, a tool for crowdsourcing bicycling collisions, near misses, and falls, offers rich data on local bicycling safety concerns. Our goal is to characterize dominant bicycling safety issues reported in nine Canadian cities. We analyzed 2,513 BikeMaps.org reports (522 collisions, 151 falls, 1840 near misses), and summarized the types of incidents reported, ratios of near misses to collisions by incident type and by city, and injuries resulting from various types of crashes. Incidents categorized as a 'dangerous pass, overtake at midblock', were most commonly reported and had the highest ratio of near misses to collision reports (9:1). Cities with a high commute mode share for bicycling had lower near miss to collision reporting ratios. Overall, 40.3% of reported collisions or falls required medical treatment. Incident types with the most severe outcomes were 'left cross at an intersection' (58.4% reported needing medical treatment); 'vehicles failing to stop at intersection or yield to bike' (54.0%); and 'multi-use paths, vehicle conflicts at intersection' (48.5%). Mitigating conditions leading to real or perceived concerns over dangerous passes by vehicles should improve bicycling comfort. Bicycling injuries will be reduced by safety improvements at intersections including those with multi-use paths.

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Crowdsourced; bicycle;
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1. Introduction

Increasing bicycling for transportation is a critical target of many cities aiming to meet sustainability goals and improve population health. To increase bicycling ridership, cities must overcome concerns, real and perceived, regarding bicycling safety, as these are the most common barriers to more bicycling (Porter et al., 2020; Willis et al., 2015; Winters et al., 2011). Specific concerns over injury from bicycle-motor vehicle collisions have been found to be a major deterrent to bicycling (Sanders, 2015; Winters et al., 2011) and bicycling specific infrastructure such as protected bike lanes is critical to improving people's access to safe bicycling (Reynolds et al., 2009; Teschke et al., 2012). However,

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many North American jurisdictions have limited bicycling infrastructure, instead leaving the vast majority of roads without any protection for bicyclists. Understanding the types of incidents and conditions that lead to collisions, falls, and near misses will help cities prioritize upgrades for bicycling transportation infrastructure.

The majority of bicycling crashes that occur are not recorded in official sources of traffic crash data such as police or insurance claims (Branion-Calles et al., 2020; Shinar et al., 2018; Winters & Branion-Calles, 2017) hindering data-driven decision-making about bicycling safety interventions. Estimates of underreporting vary based on the country being considered, but recent international comparisons found between 0% and 35% of bicycling crashes (including non-injury events) are reported to police and other official sources (Shinar et al., 2018). Bicycling collisions with motor vehicles are severely underreported to police or insurance claims (for example, only 19.5% of crashes in Vancouver, Canada were reported to police and 12.2% to insurance claims (Winters & Branion-Calles, 2017); 9% to police in Queensland, Australia (Heesch et al., 2011)). Further, crashes not directly involving motor vehicles (falls or collisions with stationary objects) are not captured in insurance data, and rarely in police data (Juhra et al., 2012), yet often account for over half of bicycling injuries (e.g., 57% Beck et al., 2016; 52% Teschke et al., 2014). Other reasons for underreporting may include distrust of police, a perception that reporting will not accomplish anything, concerns about upsetting family members or ruining a social image (Kaplan et al., 2017) and in the case of regions such as British Columbia, Canada where insurance claims are the main source of crash data (Winters & Branion-Calles, 2017), a lack of knowledge of where to report when a vehicle is not involved. Routine surveillance of bicycle safety can be prohibitive, as understanding risk factors for crashes typically requires linking incidents reported in police, insurance, or hospital data with geospatial data, or even interviews with injured bicyclists (Beck et al., 2016; Hagel et al., 2019; Teschke et al., 2014).

An additional complexity is that perceived concerns about safety are influenced by near misses (i.e., an event that was nearly a crash) (Sanders, 2015). Including near miss reports in bicycling safety analyses can offer additional data necessary to identify potential dangers (Gnoni et al., 2013) and uncomfortable scenarios for bicyclists (Aldred, 2016). Near misses are increasingly used as a proxy for crashes, particularly when crash numbers are small (Dozza, 2020). While the relationship between near misses and crashes is complex, determining the ratio of their relative frequencies in certain contexts can provide additional validity for using near misses as a surrogate measure (Branion-Calles et al., 2017; Dozza, 2020; Guo et al., 2010).

In 2014, BikeMaps.org, a global tool for crowdsourcing data on bicycling crashes, near misses, and falls was released (Nelson et al., 2015). Using a web-map, bicyclists can identify a location where they have had an incident and provide information on the nature of the incident, road conditions, as well as personal information. By 2020, BikeMaps.org has been used in over 45 countries. Promotion supported by the Public Health Agency of Canada has led to a large number of reports in several cities across Canada (Ferster et al., 2017a).

Our goal is to characterize the dominant bicycling safety issues reported in nine Canadian cities in order to help decision makers set priorities for infrastructure investments that will increase ridership and reduce injury. To meet this goal, we analyzed 2,513 BikeMaps.org reports and characterized dominant safety issues and concerns in nine

Canadian cities where BikeMaps.org has been actively promoted. We defined 10 common incident types, which people self-report as leading to a crash, fall, or near miss. Through our analysis we address four questions: 1) What are the most common incident types self-reported by bicyclists? 2) How does the relationship between near misses and collisions vary by incident type? 3) How does the relationship between near misses and collisions vary by city? 4) What incident types are leading to the most injuries requiring treatment? The results from this work will assist decision makers aiming to improve the real and perceived safety of bicycling in their cities by providing guidance on what types of investments will overcome safety concerns and reduce injury.

2. Materials and methods

2.1. Study area and data

The nine Canadian areas, listed from high to low bicycling commute mode share, are: Capital Regional District (Victoria), Whitehorse, Ottawa, Metro Vancouver, Winnipeg, Guelph, Calgary, Edmonton, and St. John's Region (Table 1). Cities range in size, bicycling culture, climate, and in how intensively BikeMaps.org has been promoted. All cities have 50 or more BikeMaps.org reports. Reflecting the diversity of contexts, the Capital Regional District has a mild climate, the highest commute mode share of bicycling (6.6%), and was the first area where BikeMaps.org was promoted (Fall 2014). A city in Canada's north, Whitehorse has a cold winter climate, the highest proportion of females bicycling to work (41.0%), and promotion of BikeMaps.org began in 2019. St. John's has the lowest bicycling commute mode share (0.2%) of cities where BikeMaps.org was promoted and can be characterized as a city with steep hills, stormy weather, and limited bicycling infrastructure.

Table 1. Study area cities with population, density, and mode share from the Canadian census 2016.

	Population	BikeMaps.org Promotion Start Date	Area (km ²)	Population Density (km ²)	Bicycle Mode Share Journey to work (%)	Proportion of commuters who are female (%)
Capital Regional District (Victoria #CMA)	367,770	Fall 2014	696	528	6.6	38.1
Whitehorse (*CSD)	25,085	Winter 2019	416	60	3.1	41.0
Ottawa (CSD)	934,243	Spring 2016	2,790	335	2.6	35.6
Metro Vancouver (Vancouver CMA)	2,463,431	Winter 2015	2,883	855	2.4	35.4
Winnipeg (CSD)	705,244	Winter 2019	464	1,519	1.8	31.2
Guelph (CSD)	131,794	Winter 2017	87	1,511	1.6	31.9
Calgary (CSD)	1,239,220	None	826	1,501	1.6	29.8
Edmonton (CSD)	932,546	Spring 2016	685	1,361	1.2	35.3
St. John's (CMA)	205,955	Winter 2017	805	256	0.2	23.1

#CMA refers to census metropolitan area and is formed by one or more adjacent municipalities centered on a population core with a high degree of integration.

*CSD refers to census subdivision and is the area equivalent to a municipality.

2.1.1. BikeMaps.org incident self-reports

Bicycling crash and near miss reports on BikeMaps.org are the primary data used in this study (details in Nelson et al. (2015)). BikeMaps.org is a global tool for self-reporting bicycling crashes and near misses. Reports include drop down menus that allow for reporting of incident conditions, sociodemographic characteristics of the person reporting, and injury outcomes. Each report also allows for a free-form description of the event. Comments enable additional context and a more nuanced understanding of the incident conditions. Hot spots of incidents, as well as how incident reports vary with time can be visualized at BikeMaps.org/vis.

As with any crowdsourcing initiative, effective promotion is key to submission of data for a given jurisdiction. Reports on BikeMaps.org generally increased following in-person promotion events geared to bicyclists such as Bike to Work Week celebration stations (Ferster et al., 2017a). Social media posts (Twitter and Facebook) and the online influence of local champions have also played a role in uptake in all cities including Calgary, which was not part of the funded promotion efforts. An earlier analysis of BikeMaps.org reports from the Capital Regional District found that most reports were made by men aged 24–35 years, with younger cyclists reporting more from the urban core and older bicyclists expanding the reports into suburban and rural areas (Ferster et al., 2017b). The gender breakdown from BikeMaps.org data used in this current analysis is presented by city in Table 2. A study of reports on BikeMaps.org from Metro Vancouver found that gender and age were not associated with the reporting of collisions relative to near misses (Branion-Calles et al., 2017). It should be noted that while cities usually have official bicycling crash data, access and completeness varies greatly across Canadian jurisdictions. In this study, we used BikeMaps.org data exclusively in order to enable consistent analysis of covariate data collected through the BikeMap.org platform. Official data available for research typically have limited attribution.

BikeMaps.org data include near miss reports, which are defined subjectively by the reporter. Evaluation of reports shows that there are some consistent differences between conditions that lead to near miss reporting, relative to collision reports. Data show that a higher odds of near miss reports are associated with commute trips, incidents involving motor vehicles, and in locations without bicycle-specific facilities (Branion-Calles et al., 2017). It is also true that the exact nature of what is reported as a near miss will vary, especially depending on the experience of the bicyclists. As the goal of this paper is to

Table 2. Number of BikeMaps.org reports by self-reported gender.

	Calgary	Capital Regional District	Edmonton	Guelph	Metro Vancouver	Ottawa	St. John's	Whitehorse	Winnipeg
Total (n)	97	824	108	71	928	221	56	80	128
					% of n				
Gender									
Men	53.6	47.3	41.7	38.0	46.7	38.0	48.2	17.5	36.7
Women	21.6	24.9	36.1	14.1	24.6	28.1	16.1	28.7	16.4
Other	2.1	0.5	0.0	0.0	1.2	0.0	1.8	0.0	0.0
Not specified	22.7	27.3	22.2	47.9	27.6	33.9	33.9	53.8	46.9

characterize reported barriers to bicycling, we see the variation of near miss reports as an important window for understanding a broad range of experiences.

2.2. Methods

2.2.1. Data pre-processing

For the nine Canadian cities we examined, we categorized each BikeMaps.org collision, fall, and near miss report to one of 10 incident types, using data from open text comments, and responses to dropdown survey questions. We grouped reports into the following (mutually exclusive) incident types: 1) conflicts with right-turning vehicles at intersections; 2) conflicts with left-turning vehicles at intersections; 3) close passes or dangerous overtaking by vehicles mid-block; 4) vehicles turning on or off the roadway mid-block; 5) vehicles failing to stop at intersections; 6) doorings; 7) incidents in roundabouts or traffic circles; 8) bicycle-vehicle incidents at the roadway interface of off-street multi-use paths; 9) multi-use path incidents involving another user; and 10) falls not involving a motor vehicle. These 10 categories represent the most common types of incidents collectively in our study cities, capturing 2,513 (71%) of reported incidents. Reports that did not fit these categories or lacked sufficient detail for interpretation were excluded from the current analysis, totaling 1,019 (29%). To corroborate the circumstances surrounding the event with those provided by the reporter, the location of the incident was viewed both on the BikeMaps.org website and in Google Streetview. Incidents initially reported as near misses, but that resulted in an injury or if it was clear from the description that the bicyclist collided with an object or fell, were recoded as collisions or falls for this analysis.

2.2.2. Data analysis

To determine the most common incident types, we summarized the frequency and proportion of near misses and collisions, overall and for each city. We calculated the ratio of near misses to collisions (where higher numbers indicate more near misses reported relative to collisions) by incident type and for all incidents by city. To quantify uncertainty in these point estimates we used bootstrapping with 5,000 replications to estimate 95% confidence intervals based on percentiles (Chernick & LaBudde, 2011). In order to contextualize the near miss and collision reporting trends between cities, the ratios were compared to the commute mode share of bicycling using bootstrapped simple linear regression.

Finally, we conducted a sub-analysis using only collision reports to assess incident severity (injury requiring medical treatment; or injury not requiring treatment, no injury, or unknown outcome). By incident type, reports for either injury category were summarized by frequency and proportion.

3. Results

3.1. What are the most common safety incidents self-reported by bicyclists?

In Table 3 we show the 10 most commonly reported incident scenarios across all cities. The most common incidents reported on BikeMaps.org were ‘dangerous pass, overtake at midblock’ (22.6%), ‘right turning vehicle at intersection’ (18.9%), and ‘vehicles failing to stop at intersection or yield to bike’ (14.8%).

Table 3. Near misses, collisions, and the ratio of near misses to collisions by incident type.

Incident Type	N Reports (%)	Near Misses	Collisions	Ratio (95% CI) ^a
Dangerous pass, overtake at midblock	569 (22.6)	527	42	12.55 (9.42, 17.83)
Right turning vehicle at intersection	474 (18.9)	352	122	2.89 (2.38, 3.57)
Vehicles failing to stop at intersection or yield to bike	372 (14.8)	322	50	6.44 (4.87, 8.95)
Mid-block vehicle turns	294 (11.7)	196	98	2.00 (1.58, 2.57)
Left cross at an intersection	248 (9.9)	171	77	2.22 (1.71, 2.93)
Falls	158 (6.3)	7	151	0.05 (0.01, 0.09)
Multi-use path vehicle conflicts at intersections	145 (5.8)	112	33	3.39 (2.35, 5.21)
Incidents in roundabouts & traffic circles	95 (3.8)	68	27	2.52 (1.62, 4.18)
Dooring	81 (3.2)	44	37	1.19 (0.76, 1.89)
Multi-use path, other users	77 (3.1)	41	36	1.14 (0.71, 1.79)

Ratio = Near Misses/Collisions

^a95% bootstrapped confidence intervals with 5,000 replications.

In [Figures 1 and 2](#) we show the proportion of reports for each type of incident, overall and by city. While reports vary by city, in almost all cities ‘dangerous pass, overtake at midblock’ and ‘right turning vehicle at intersection’ were common. Some of the differences between cities may be associated with the size of the city ([Table 1](#)). For example, Whitehorse is a sparsely populated community and did not report issues with ‘left cross at an intersection’. St. John’s has the lowest bicycle to work mode share (0.2%) and most incidents reported were ‘dangerous passes, overtake at midblock’.

3.2. How does the relationship between near misses and collisions vary by incident type?

In [Table 3](#) we show that ratio of near misses to collisions by incident type. In general, there are 2.7 times as many near misses reported as there are collisions, but the specific ratio varies widely by incident type. The incident category ‘dangerous, pass overtake at midblock’ had the highest ratio of near misses to collisions, with 12.5 near misses reported for each collision. ‘Failing to stop at intersection or yield to bike’ also had a high near miss to collision ratio, with 6.4 near misses per collision in the dataset.

3.3. How does the relationship between near misses and collisions vary by city?

The ratio of near misses to collisions also varies by city ([Table 4](#)). In Calgary, the Capital Regional District, and Metro Vancouver there were relatively low numbers (~2 to 3) of near misses reported relative to collisions. In comparison, in St. John’s there were approximately 6 near misses reported for each collision. Variation in the ratio of near miss to collision reporting by city was compared to cities’ bicycling commute mode share ([Figure 3](#)). Specifically, we see an inverse relationship between bicycling commute mode share and the ratio of near misses to collisions, where cities with lower bicycling commute mode share have a higher ratio of near misses to collisions reported ($R^2 = 0.22$).

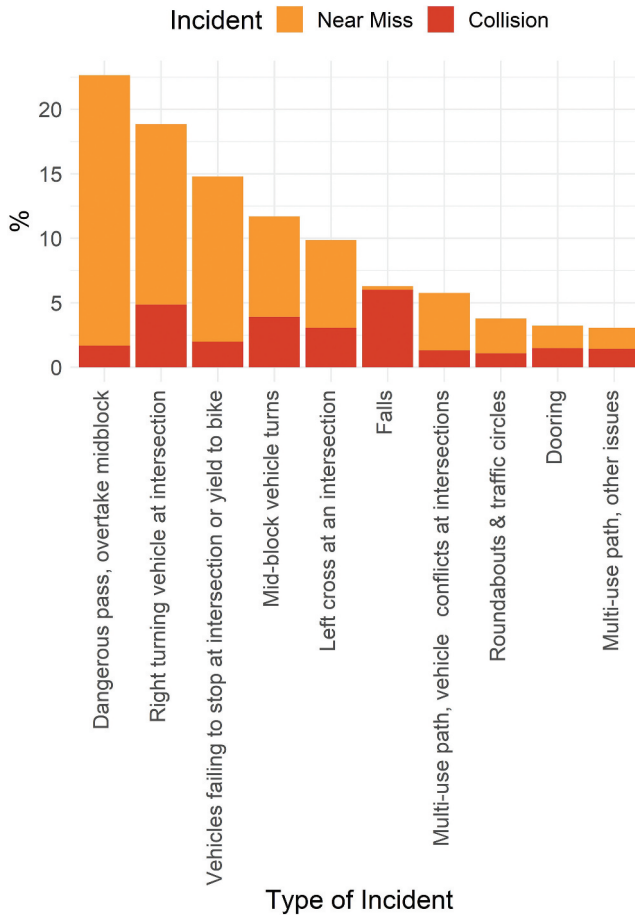


Figure 1. Proportion of near misses and collisions by incident type across all cities.

3.4. What incident types are leading to injuries requiring medical treatment?

When reporting an incident on BikeMaps.org, bicyclists can report whether they were injured in the collision or fall and if they sought medical treatment, which can be considered measures of severity. For this analysis, we grouped all incidents where medical treatment was received. In Table 5 we present the severity trends by injury type. Of the 673 collisions, 467 (69.4%) resulted in injury, while only 271 (40.3%) required treatment. The incident type with the most severe outcome was ‘left cross at an intersection’, where 58.4% of reported incidents required medical treatment. Medical treatment was required for 48.5% of the reported incidents ‘multi-use path, vehicle conflicts at intersection’. In contrast, while ‘right turning vehicle at intersection’ is the second most common type of incident, it had the lowest proportion of incidents that required medical treatment (27.0%). The largest absolute number of both collisions and injuries were from falls.

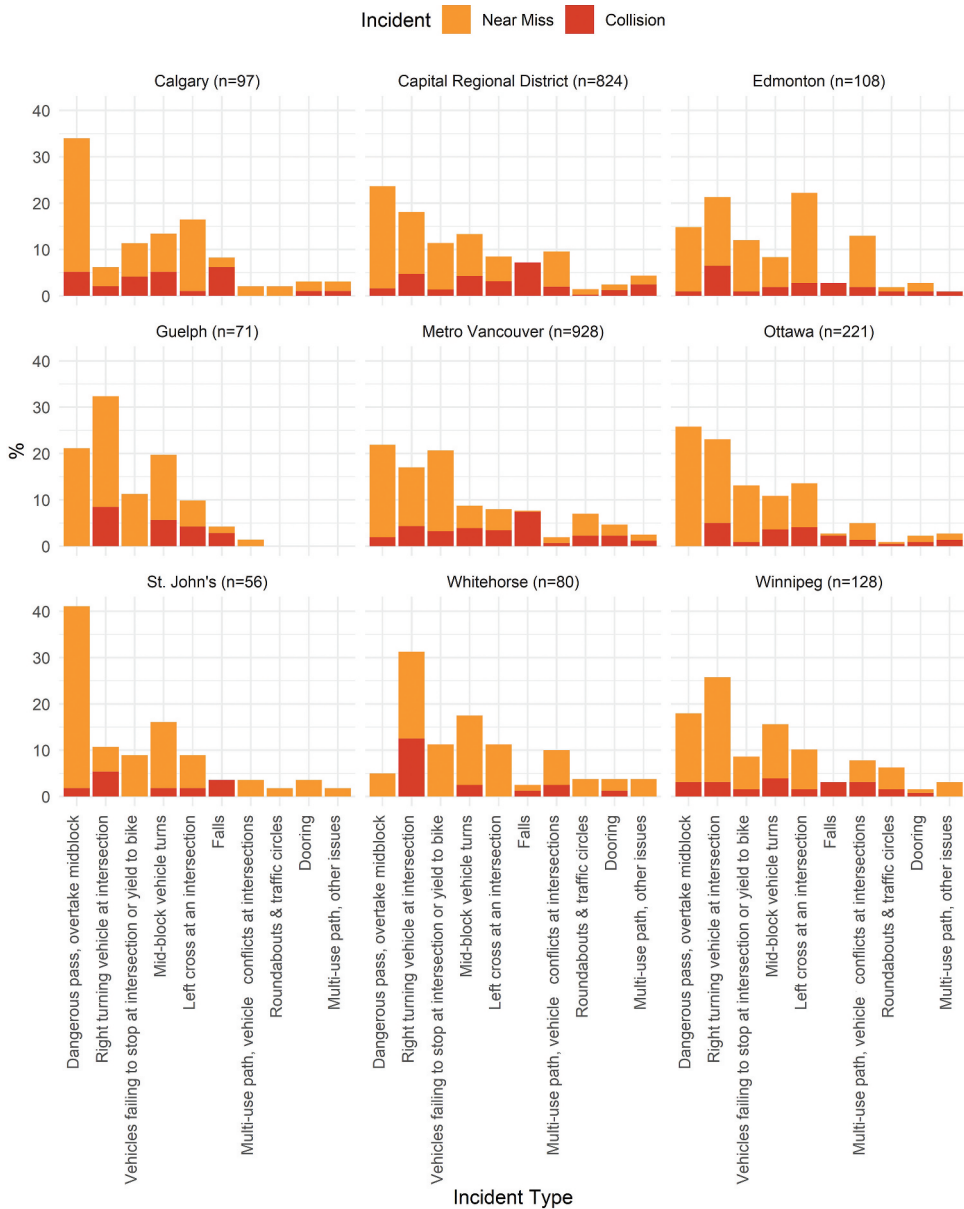


Figure 2. Proportion of near misses and collisions by incident type per city.

4. Discussion

Crowdsourced tools, such as BikeMaps.org, provide an approach to address the bicycling safety data gap. BikeMaps.org, which has over 10,000 reports globally, including >3500 reports in just nine Canadian cities, provides data on safety concerns and barriers to bicycling. In Canada, the three most common incidents reported to BikeMaps.org were

Table 4. Near misses, collisions, and the ratio of near misses to collisions by city.

City	Near misses	Collisions	Ratio (95% CI)
St. John's	48	8	6.00 (3.13, 17.00)
Ottawa	177	44	4.02 (2.95, 5.74)
Whitehorse	64	16	4.00 (2.41, 7.67)
Edmonton	86	22	3.91 (2.59, 6.75)
Guelph	56	15	3.73 (2.21, 7.38)
Winnipeg	100	28	3.57 (2.43, 5.71)
Calgary	72	25	2.88 (1.85, 4.76)
Capital Regional District	593	231	2.57 (2.21, 3.00)
Metro Vancouver	644	284	2.27 (1.98 2.62)

Ratio = Near Misses/Collisions

^a95% bootstrapped confidence intervals with 5,000 replications.

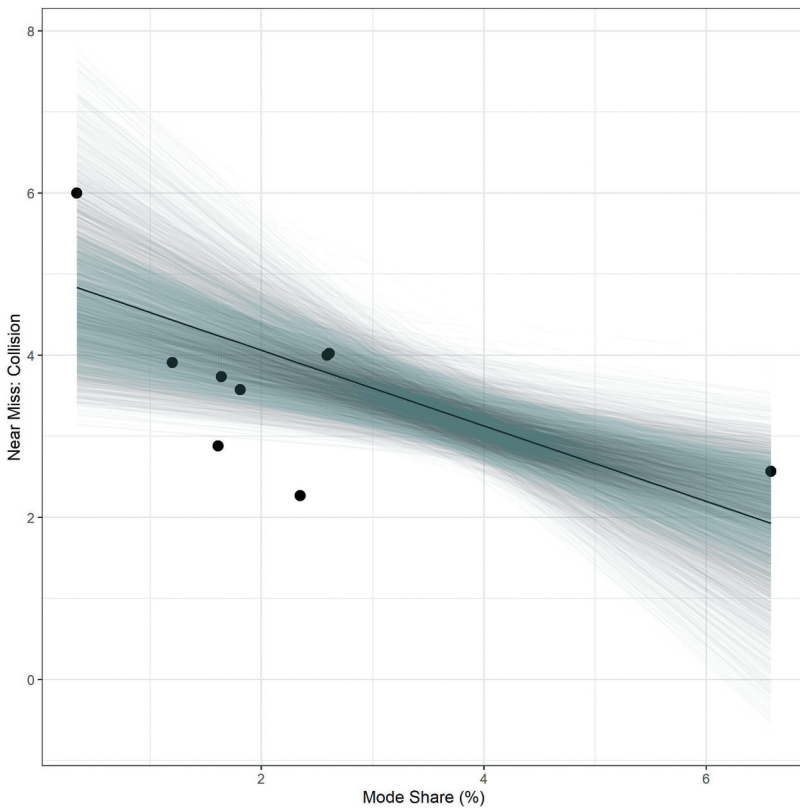


Figure 3. The linear relationship between the near miss to collision ratio and bicycling mode share for each city. Points represent observed near miss to collision ratios in each city, light grey lines represent a linear fit for each bootstrapped sample, and the black line represents the mean linear fit over all bootstrapped samples.

‘dangerous pass, overtake at midblock’ (22.6%), ‘right turning vehicle at intersection’ (18.9%), and ‘vehicles failing to stop at intersection or yield to bike’ (14.8%).

Bicyclists in St. John’s, Calgary, the Capital Regional District, Metro Vancouver, and Ottawa reported ‘dangerous passes, overtaking at midblock’ most often. The provincial government of Newfoundland and Labrador had adopted a minimum passing law in

Table 5. Percentage of collisions that required medical treatment by incident type.

Incident Type	No treatment	Injury with medical treatment	% requiring treatment (95 CI%) ^a
Left cross at intersection	32	45	58.4 (47.2, 69.9)
Vehicles failing to stop at intersection or yield to bike	23	27	54.0 (39.6, 68.0)
Multi-use paths, vehicle conflicts at intersections	17	16	48.5 (31.4, 66.7)
Mid-block vehicle turns	58	40	40.8 (31.4, 50.5)
Incidents in roundabouts & traffic circles	16	11	40.7 (22.2, 60.9)
Dooring	22	15	40.5 (25.0, 57.1)
Falls	93	58	38.4 (30.8, 46.2)
Multi-use paths, other users	23	13	36.1 (20.0, 51.7)
Dangerous pass, overtake at midblock	29	13	31.0 (17.5, 45.5)
Right turning vehicle at intersection	89	33	27.0 (19.5, 35.4)

^a95% bootstrapped confidence intervals with 5,000 replications.

March 2019; this could have contributed to heightened awareness by bicyclists in St. John's, where 40% of reports were dangerous passes. St. John's currently has little functioning dedicated on-street bike infrastructure (Google Streetview; St. John's, 2019). Minimum passing distance laws have become increasingly common in jurisdictions where bicycles continue to share the roads with vehicles instead of having dedicated infrastructure. However, their effectiveness has been called to question given issues with enforcement (Lamb et al., 2020). Further, a Spanish research study found that perceived risk was usually associated with higher vehicle speeds and the presence of heavy vehicles and less so by lateral separation (Llorca et al., 2017). Despite challenges with enforcing close passing laws, Schramm et al. (2016) found an increase in driver awareness of bicyclists following implementation of a minimum passing law in Queensland, Australia. A video study from Ottawa found that over 90% of vehicles passed with over 1 m of lateral separation, as Ontario provincial law dictates, and that traffic density as well as passing distance affected bicyclist comfort (Apsanore et al., 2017). Mid-block crashes such as a bicycle being overtaken by a vehicle have been less studied than those in intersections yet tend to be more severe due to increased motor vehicle velocities (Pai, 2011).

Another common incident type, 'right turning vehicle at intersection', may be ameliorated by relatively low-cost infrastructure interventions such as green box treatments (Dill et al., 2012). These move the bikes in front of vehicles when stopped at intersections, although they may not provide safety benefit for bicyclists during the latter phases of a green light (Jannat et al., 2020). Many cities are adopting concurrent green light phasing for bicycles and vehicles to eliminate right-turn conflicts, especially in conjunction with cycle tracks (Furth et al., 2014).

'Vehicles failing to stop at an intersection or yield to bikes' was the third most common type of report made and has been noted as a critical concern for bicyclists in other studies (Schramm et al., 2010). Notably, failing to stop or yield also had the highest ratio of near misses to collisions, meaning that even when no collision occurs, vehicles failing stop at intersections is concerning to bicyclists. Drivers failing to stop or yield was especially high in Metro Vancouver, accounting for 192 (of a total of 928) reports. Many of these reports occurred along local street bikeways with 2- or 4-way stops, with the person describing the driver as not yielding properly. For example, „I waited my turn at the

4-way stop. Had to slam on the brakes mid-intersection to avoid being hit by a lady driving a newer SUV who did not stop at all at the stop sign coming up the hill on Yukon. She was looking down, and may have been using a cell phone,.

The importance of near misses should not be undervalued, especially if the goal is increasing bicycling for transportation, as the psychological impact of near misses has been shown to reduce bicycling in the future (Sanders, 2015). Our analysis helps quantify how near misses may be related to collisions and highlights that there is variability in how a near miss is perceived or defined depending on the conditions of the incident and bicycling culture in a city. As shown by Branion-Calles et al. (2017), the ratio of near miss to collision reporting tends to be higher when a vehicle is involved and the perceptions of risk may be higher (e.g., ‘vehicles failing to stop at an intersection or yield to bike’, ‘dangerous pass, overtake at midblock’, or ‘left cross at an intersection’). Differences between cities in terms of supporting a comfortable riding environment may contribute to higher rates of near miss reports relative to collisions. In contrast, ‘falls’, which in our analysis are single bicycle crashes that do not involve a vehicle or another moving object, are rarely reported as near misses. Understanding the ratio of near misses to collisions by crash circumstance as offered by this work provides a better understanding of when and how near misses can be used as a surrogate for crash data (Dozza, 2020). Our analysis also suggests that near miss reporting, relative to collision reporting, may be higher when bicycling commute mode share in a city is low and could be explained by the idea of safety in numbers, which shows that people riding bicycles are proportionately safer when more people are bicycling (Jacobsen, 2003).

Falls have a high risk of injury (DeRome et al., 2014), and often highlight the role of the physical environment in safety. In this study, we categorized incidents that did not involve a motor vehicle or another user as a fall. Across all sites, falls were responsible for the largest number of reports of collisions (151) and the largest number of reports of respondents seeking medical treatment (58). Injury severity is missing from police or insurance data and highlights the utility of BikeMaps.org in filling in this data gap.

Another type of incident that had a more than half (58.3%) of people requiring medical treatment is ‘left cross at an intersection’. When vehicle drivers make left turns it is estimated risks to pedestrians increase four times compared to when a vehicle is proceeding straight (Lord, 1996). In the book *No Accident* (2014), Neil Arason puts forward the idea that the complexity of a left turn for vehicle drivers is simply incompatible with simultaneous through traffic of pedestrians and cyclists. Few studies to our knowledge have examined risk of the left cross for bicyclists, thus, these reports on BikeMaps.org contribute to a better understanding of the risks involved when there is no signal phase separation.

An interesting aspect of the BikeMaps.org data is reporting along multi-use paths. Most official reporting does not capture incidents that happen along multi-use paths, given existing biases toward reporting incidents that involve vehicles (Jestico et al., 2017). However, multi-use paths can have high ridership and potential for safety issues (Ferster et al., 2021). While people often perceive multi-use paths as low risk, it has been suggested that risks are much higher due to conflicts with other path users (Winters et al., 2012), and interaction with vehicles when multi-use paths cross the road network (Jestico et al., 2017). In our analysis, half of the incidents on multi-use paths involving vehicles require medical treatment, which suggests that both the frequency and

magnitude of these incidents should be addressed if aiming to improve safety for bicyclists. Few near misses were reported with other trail users, which may suggest that these events are perceived as low risk.

While BikeMaps.org is increasing the data available for bicycle safety research and planning, data are biased towards people who have access to technology. We have studied the gender and age bias and patterns in reporting, and Ferster et al. (2017b) identified bias towards men and people aged 25–44. The trends that we highlight in this paper are an overview of the self-reported concerns and incidents experienced by Canadian bicyclists and we recognize that this is a sample rather than a complete enumeration. An important aspect of crowdsourcing is that it provides a platform for community voices to emerge. The results of this work document what Canadian bicyclists are self-reporting to be their experience.

5. Conclusion

While increasing the number of trips taken by bicycle is a priority in many North American cities, there are critical gaps in the data needed to make decisions on infrastructure investments and other pro-bicycling policies. BikeMaps.org is a crowdsourced tool that is filling a key data gap on safety issues and barriers to bicycling. This research highlights what bicyclists are experiencing, and while this is a sample of issues from BikeMaps.org users, it provides a starting point for understanding specific interventions that will increase real and perceived safety. To increase bicycling safety and comfort, cities should prioritize investment in infrastructure that separates bicycles from motor vehicles and reduces conflict between vehicles and bicyclists in intersections. Further, our results indicate that safer intersection conditions have the potential to reduce serious injury among bicyclists, especially measures that mitigate the danger of left-turning vehicles or provide safer road crossings along multi-use paths.

As BikeMaps.org has matured as a project, so has our approach to data collection and outreach. The next phase of data collection will include more focus groups and stakeholder engagement to encourage data collection from people who are underrepresented including women, youth, older adults, low-income people, and new bicyclists. Our team is also developing tools to engage people who are mobility limited and interested in increased access to all modes of active transportation.

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