Review Article

Safety and risk factors associated with electric scooter use globally: A literature review

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Abstract

Electric kick scooters (e-scooters) are a form of micro-mobility devices that have been implemented in city streets worldwide as a viable travel solution. E-scooter companies have launched in over 100 U.S cities and various international countries, including Europe, Australia and New Zealand. On January 1st, 2020, Ontario launched its pilot program to permit e-scooters onto provincial roads. Due to the implementation and recent growth of this new technology, it is important to evaluate what is already known about e-scooter use and what remains to be discovered. We conducted a literature review to understand the general prevalence of e-scooter usage, common injury patterns, demographics of patients commonly involved in e-scooter injuries, and risk factors associated with injuries. We also sought to understand the current legislation surrounding e-scooter use in Ontario, other provinces across Canada, and other countries. Common injuries included: extremity fractures, facial fractures, lacerations and head injuries (including concussions and intracranial hemorrhages). Most commonly injured riders were men between 20- 40 years old, and our findings indicate that limited helmet use and acute alcohol intoxication may contribute to e-scooter injuries. These findings can help to direct future research questions and prepare primary care and emergency room physicians for the potential surge in e-scooter use here in Ontario, Canada.

Keywords: Electric scooter, E-scooter, Rideshare, Scooter share, Safety, Legislation, Canada, Pediatrics, Pediatric health

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Introduction

Dockless electric scooters (e-scooters) are battery-powered two- or three-wheel motorized vehicles which can be dropped off and picked up from arbitrary locations in a service area (1). In 2017, Bird launched as the first dockless e-scooter rideshare company. It was promoted as an environmentally friendly form of micro-mobility, and a solution to traffic congestion and the 'last-minute mile' problem (2). Today, ride-share companies that provide e-scooters make use of mobile applications that allow users to rent scooters by the minute similar to services like Uber, Lyft, and other taxi companies (1).

There are many advantages to e-scooter travel that makes their use attractive. E-scooters are considered convenient. As a form of 'first-mile/last-mile travel', they can connect urban users to a transit hub, and allow users to easily cross short distances that are too long to walk but too short for a drive (2). Initiation of e-scooter rental is easy and simply requires riders to engage with the ride-sharing company's mobile phone app. Users can find a scooter, open their corresponding app, and scan the scooter's QR code to 'unlock' the scooters. After arriving at their destination, users then lock the scooter and end their trip by taking a picture of the QR code. Users can drop off e-scooters 'almost anywhere' as long as users follow the parking guidelines set out by the city officials (2). The relatively low cost of e-scooters also makes them an attractive form of transportation (3). Furthermore, e-scooters have been touted as an environmentally friendly mode of transportation, as they run on electric batteries instead of fossil fuels (3). Compared to e-bikes, e-scooters appear to be easier to operate and reportedly feel safer to users (3). According to a study conducted in 2018, 70% of those surveyed across the US view e-scooters positively (4). In another study, 22% of people who had spent time in an area where they saw e-scooters available for rent said they had tried to use one at least once, despite the fact that many riders (27%) said they were uncertain of which traffic laws to follow (5). Over the years, the use of e-scooters has grown in popularity across North America and worldwide (6).

However, there are many disadvantages associated with e-scooter use that makes their implementation controversial (3). Reports have shown that e-scooters are often left in unauthorized places, which leads to issues such as blocked pedestrian pathways (3). E-scooters tend to have relatively short battery life (3), require good weather conditions to function properly and are susceptible to damage from bad terrain (3). Moreover, the claim that e-scooters are eco-friendly has also been contested, as the lithium battery needs to be replaced every 300-1000 charges, and many cities are not currently able to process/recycle these batteries appropriately (3). The most troubling drawback of e-scooters is the safety issues surrounding this vehicle. Since the Fall of 2018, at least 1500 injuries have been reported in the United States while using a rentable e-scooter (7), and at least eight resulted in deaths.

With these concerns in mind, many Canadians wonder how the introduction of e-scooters will impact the safety of our general and pediatric populations. As the Ontario government recently enacted a pilot project in January 2020 to legalize e-scooters (8), it is critical to evaluate what is already known about this technology. To prepare healthcare providers for the potential surge in this technology, it is important to determine which populations use e-scooters and what

kinds of injuries are associated with their use. Not only will emergency room physicians likely be treating patients that present with these injuries, but there may be a role for primary care physicians to counsel their patients on how to engage with this technology in a safe way. This review will summarize data collected on e-scooter use including prevalence, common injuries, demographics of injured patients and potential risk factors for injuries. Using these results, we will propose areas for future research.

Methods

First, a comprehensive search of peer-reviewed journals was completed based on a wide range of key terms, including: *Power scooter, e-scooter/escooter/electric scooter, mobilized scooter, and scooter share, Canada, safety, legislation,* and *current use.* These terms were combined in various ways, with "AND", "OR", and "WITH" commands in between terms to obtain the most narrowly defined and appropriate articles. This process was completed initially through the McMaster University Library search database. Six databases were searched, including Google Scholar, Pubmed, Web of Science, MEDLINE, Embase and CINAHL. Second, a comprehensive search of grey literature was completed to identify publications including annual reports, research reports, working papers, newspaper articles, editorials/commentaries, and government documents. The key terms used to complete the search were the same as those listed above in the search amongst peer-reviewed journals. The search engine used for this process was primarily Google. Finally, the 'Snowball Method' was used to identify relevant articles, where the works cited section for each article found was reviewed in order to find additional articles.
The reliability and credibility of all articles were considered and evaluated by authors.

This evaluation was based on the quality of content, the relevance to the topic, the published year, and the citation frequency (if applicable). In investigations of the identified articles, general themes were identified. Through an iterative process, the authors grouped these themes into four important dimensions using our clinical experience and/or role as educators to guide the analysis.

Results

Our search process ultimately found 33 articles written from 2018 – 2020. The findings from these articles revealed three major sub-topics: i) expected use and legislation in Ontario and previous use in Canada, ii) previous injuries reported in the literature, and iii) potential risk factors for e-scooter related injuries.

Expected use and legislation in Ontario and previous use in Canada

On January 1st, 2020, Ontario launched its pilot project to permit e-scooters onto provincial roads (8). The pilot project was enacted as a way to "expand business opportunities and help cut down congestion on provincial roads" (8). The goal was to evaluate the use of e-scooters in Ontario over a five-year 'trial' period, during which lawmakers will have the ability to examine the general safety of e-scooters and their ability to integrate with local traffic and other vehicles (9). Ultimately, lawmakers will decide at the end of the five-year project if the existing legislation is adequate to appropriately regulate e-scooter use (9).

The province has established broad rules and requirements for e-scooters but has left it up to individual municipalities to create and pass bylaws tailored to the local regulation of e-scooters (9). Province-wide rules indicate that riders must be at least 16 years old and must wear a helmet while driving the vehicles if under 18 years of age (8). The law states that an e-scooter helmet must be made to the standard of a bicycle helmet, rather than one designed to withstand the impact of a collision of a motorcycle (10). E-scooter vehicles must weigh under 45 kilograms (8), must be equipped with a horn or bell, have one white light in the front, one red light in the back, and reflective material on the sides (11). E-scooters are permitted to travel up to a maximum speed of 24km/hr but are not allowed on controlled-access highways (9).

Given each municipality's discretion over which bylaws to enact into regulation, the rules governing the use of e-scooters may vary from municipality to municipality. Therefore, municipalities have the ability to limit and/or ban the use of e-scooters altogether (11). Municipalities that permit e-scooters will be responsible for designating areas where e-scooter use is permitted such as municipal roads including parks and trails, the location of parking spaces, and how e-scooters will be managed in each municipality. Although a best practices document was developed by the ministry to guide individual municipalities in their adoption of e-scooters (9), the sudden proliferation of scooters in city roads has prompted fears that the technology is outpacing regulation (10). The Ministry of Transportation expects that this pilot project will yield enough meaningful evidence on the safety and feasibility of e-scooter use to determine if a permanent framework should be established (8).

E-scooters have previously been made available under pilot projects in other provinces, including Quebec and Alberta (12). In September of 2018, a notice of motion was approved in Calgary to implement a two-year dockless bicycle share pilot project, which included the ability to add other shared transportation options (13). In addition to piloting the dockless bicycle share services, the City of Calgary concluded their 16-month pilot program to test the viability of e-scooters in the city in November 2020 (13). For this pilot project, the city allowed third-party operators with a set number of shared e-scooters, to access city sidewalks, exclusive bicycle lanes and parks and pathways (14). Montreal also introduced e-scooters in June 2019, with the intention to offer more environmentally friendly modes of transportation. Two dockless ride-sharing companies, Lime and Bird, were allowed to operate, before the pilot project came to what was expected to be a brief pause for the winter in November 2019 (15). However, in

February 2020, the city of Montreal decided to ultimately ban Lime and Bird e-scooters from the roads after riders kept violating the rules associated with their use (15). The city claimed the scooters were often left abandoned in the middle of high traffic streets, and often left right outside metro stations (15). It was ultimately reported by ministry officials that just 20% of the vehicles were parked in their designated spaces and that the city didn't want to 'police e-scooters' (15).

Sociodemographics and clinical trends of injuries reported in the literature

Several case reports and case series completed across the world have characterized the types of injuries, patient demographics and the clinical outcomes commonly associated with e-scooter use. The first scientific study in the United States to assess the types of injuries associated with e-scooter use was conducted by Trivedi et al. (16). By characterizing the injuries of patients presenting to emergency departments in Southern California over the course of one year, they found that injuries associated with standing electric scooter use were mostly minor but could be severe and costly (16). They noted similar patterns of injury as Segways but pointed out that standing electric scooters were more economic and more accessible to the general public than Segway transporters, and therefore could have a substantially greater impact on public health given their popularity. Trivedi *et. al* found that riders themselves were most injured, suffering from fractures, head injuries, and soft tissue injuries (32%, 40% and 28%, respectively). These results agreed with the findings of Nellamattathil and Amber, who found that musculoskeletal injuries (with a predilection to the upper extremity) were the most common injury pattern noted (6).

On the other hand, Kobayashi et al. found that one-third of patients presenting to level 1 trauma centers in California required operative intervention, (the majority of which were open extremity and/or facial fractures (17). Schlaff et al. found that through the 15-month dockless pilot period in Washington, DC, 13 patients suffered injuries serious enough to merit neurosurgical consultation. Specific injuries included skull fractures, central cord syndromes, and vertebral compression fractures. One patient showed symptoms that required procedural intervention by a neuro-interventional radiologist and one patient was pronounced dead soon after arrival to the hospital (18). A report from Austin Public Health found that though the majority of patients (70%) suffered injuries to the upper limbs (hands/wrist/arm/shoulder), half of identified riders (48%) had injuries (fractures, lacerations, abrasions) to the head, and fifteen percent of riders had evidence suggestive of traumatic brain injury (19). Kobayashi et al. found that extremity fractures were again the most frequent injury (42%), followed by facial fractures (26%) and intracranial hemorrhage (18%) (17).

Trivedi et al. (16) noted that though riders of electric scooters were required to be at least 16 years old by state law (and 18 by company rental agreements), there was a small proportion (10.8%) of patients that presented with e-scooter injuries who were younger than 18 years old. One of the conclusions from this study was that it "suggests that self-enforced regulations

imposed by private electric scooter companies may be inadequate." This finding was similar to that of Ishmael et al., who looked at operative orthopaedic injuries associated with electrical scooter incidents in California. They found that though mean patient age was found to be 35 years old, 4 of the patients they analyzed were paediatric patients.

Many results point to increased injuries over time following the introduction of ride-share programs. Kobayashi et al. found that during their study period, monthly admissions of patients with e-scooter related injuries increased significantly over time (17). Officials at Austin Public Health saw two injuries occurred per day on average throughout the period they conducted their study (19). E-scooter injuries dramatically increased in Auckland following the launch of e-scooter systems in October 2018 (20), with the rate of injuries increasing from two injuries per week before their introduction to an average of 35 per week post-introduction of ride-sharing programs (20). In Dunedin, New Zealand, there had been no e-scooter related emergency department (ED) presentations the year before the e-scooter sharing service was introduced. Post-introduction, 56 e-scooter related ED presentations from 54 separate events were identified in 2019, one year after the e-scooter sharing service was introduced (21).

Many studies revealed a specific pattern in the type of rider that is most commonly injured in e-scooter accidents. An epidemiological study conducted by Public Health officials, in Austin, Texas from September to the end of November 2018, found that the majority of patients were riders themselves, and the majority of patients identified as male (19). Riders ranged from 9-79 years old, with nearly half (48%) aged between 18-29 years old. Similarly, Kobayashi et al. found that the majority of patients were between the ages of 20-40 years old, with a mean of 37.1 years (17). The majority (65%) were also male. Blomberg et al. conducted a study evaluating patients injured in e-scooter rides in Copenhagen and similarly found that the majority of patients, themselves riders, were between 18-25 years old. Non-riding patients were mostly elderly people who had tripped over scooters, causing them to sustain moderate to severe injuries (22). No obvious trends in terms of ethnicity or cultural background of injured patients have been noted thus far.

Potential risk factors associated with e-scooter use

Among various studies, lack of helmet use was found in almost all riders; Dimaggio et al. found that less than 1% of injured riders wore a helmet (23), while Trivedi et al. found that just 4% of all patients were wearing a helmet, despite California laws making helmet use mandatory at the time the study was conducted (16). Jay Doucet, M.D., chief of the trauma division at the University of California San Diego Health Hospital, says that his facility 'has admitted more than 150 e-scooter-related major trauma victims since Jan. 1st, 2019, and just 2% of victims he treated were wearing helmets when they crashed' (5). During a public observation component of their study, Badeau et al. reported that lack of helmet use was observed in 94.3% of riders (24).

In addition to lack of helmet use, Kobayashi et al. also found that almost half (48%) of e-scooter riders were alcohol-impaired at the time of presentation to the emergency department (with a blood alcohol level >8 mg/dL) (17). Blomberg et al. conducted a study evaluating patients injured in e-scooter rides in Copenhagen and also found that many patients were under the influence of alcohol or other drugs (22). Alcohol consumption while riding e-scooters has also been identified as a significant risk factor in e-scooter accidents in several studies (17,20,22,24,25). Bekhit et al. found that alcohol consumption was found to be a contributing factor in 29% of all e-scooter related injuries (20), while Badeau et al. found that 16% of injured patients reported alcohol intoxication (24).

Discussion

Given the infancy of ride-sharing programs for e-scooters, research is still in its early stages. With the sudden rise, popularity and accessibility of these scooters in major metropolitan areas, healthcare workers need to be educated and prepared for the expected increase in the use and abuse of e-scooters in the coming years.

It is important to compare the incidence and types of e-scooter related injuries in paediatric and adult riders to injuries sustained by riders utilizing other forms of 'last-minute mile' transportation. For example, previous studies have shown that manual scooters, (sometimes referred to as 'kick scooters') are 'relatively safe', with a small number of accidents overall (26). Some studies have demonstrated that manual scooter injuries tend to be 'minor to moderate' (26) in nature, and typically include fractures and contusions in various areas (26). To the authors' knowledge, there are currently no studies that directly compare e-scooter use/injuries to that of manual scooter use/injuries. Future studies should focus on directly comparing e-scooter injuries to that of manual scooter injuries such that their absolute risk can be properly assessed and understood.

On the other hand, electric bikes (e-bikes) are another popular form of micro-mobility for youth and adults, whose injuries have become a major health concern in recent years (27). Previous studies have also shown that the locations (often face and head) and types of injuries (often fractures) are similar between regular/non-e-bikes and e-bikes; however, often e-bike related trauma is more severe in nature (28). Specifically, e-bike injuries tend to result in higher injury severity scores (ISS), longer patient stays in hospital, and higher percentages of patient admission to ICU (28, 29). Previous studies have also indicated that when it comes to e-bikes, children are more likely to suffer from head and face injuries more often than their adult counterparts (28). However, various personal blogs, consumer reviews, and online newsletters have compared e-scooters and e-bikes and have touted e-bikes as the 'obvious choice for safety' (30, 31). The lack of studies comparing e-scooters to other forms of micro-mobility and various forms of motorized vehicles limits users and physicians from understanding the risk of this technology in a greater societal context. A nuanced understanding of this risk is essential in enabling physicians to have open conversations with their patients and answer questions related

to this technology. As such, future studies should therefore directly compare e-scooter related injuries to e-bikes, as well as other forms of transportation, including Segways, and Hoverboards. This will help to understand the implications of this technology in a broader context. As well, major organizations like the Canadian Pediatric Society (CPS), the Canadian Academy of Sport and Exercise Medicine (CASEM), and other organizations could use this information to issue position statements regarding appropriate use guidelines for consumers, as well as counselling guidelines for primary care practitioners.

As it stands today, much remains unknown about the current risk factors associated with e-scooter injuries. Our review has identified three areas that should be the focus of future research: (i) the role of alcohol use, (ii) lack of helmet use, and (iii) specific usage patterns and common injuries in Canadian paediatric and adult populations. It is of utmost importance that future studies characterize the risks that alcohol and lack of helmet use pose to e-scooter riders. Currently, the reason for the profound lack of helmet use is unclear. It has been suggested that perhaps many riders do not want exposure to lice or germs that could be found in shared helmets provided by the ride-sharing program. As well, many make a spontaneous decision to ride while they're already out and do not have access to a helmet (23). Kobayashi et al. found that 98% of the patients in their study were not wearing a helmet and attributed this high proportion in part to the lack of legislation in the USA requiring helmet use with e-scooter devices (17). Allem and Majmundar found that posts to Bird's official Instagram page rarely showed e-scooter being used with protective gear (32), and only 1.54% of posts mentioned protective gear in the comment box (32). The authors argue that even though Bird offers free helmets to all active riders, 'reposting its customers' photos without wearing protective gear signals that Bird approves of its customers riding without a helmet (32). Future studies can further explore how social media use influences rider behaviour and the clinical implications of marketing decisions.

Lack of helmets could potentially be a problem for paediatric populations. A 2017 survey conducted but the American Academy of Paediatrics (AAP) found that parents were less likely to make their child or adolescent wear a helmet while riding a scooter when compared to riding a bike (33). While many cities have placed age restrictions on those who can legally ride e-scooters, these vehicles remain easily accessible to minors (33). Most ride-sharing programs do not have a way to verify the user's age, so children and teenagers have the ability to sign up and rent e-scooters without parental consent so long as they have access to a mobile app and a credit card (33).

We also call for the initiation of future research analyzing the common injuries that paediatric and adult populations present with. These studies will help better prepare primary care physicians for patient counselling when it comes to engaging with this technology. In the past, Canadian paediatricians have counselled and warned against the use of backyard trampolines (34) and have provided evidence-based guidance around the healthy and meaningful use of 'screen time' and social media (35). Family doctors have taken on a similar role, previously warning their patients about the health implications of various new forms of technology, from genetically modified food (36) to 'Black Henna Tattoos' (37). We believe that counselling

around e-scooter is not only warranted, but necessary should future studies continue to show that this technology poses a significant health risk to paediatric and adult populations.

Finally, future research can be used to assist emergency room physicians navigate the potential increase in e-scooter use. Ultimately, treatment algorithms can be created for primary care and emergency department physicians to follow when treating patients presenting with e-scooter related injuries (for example, if patients present with a head injury, order non-contrast head CT; if patients do not present with a head injury, begin by…). Additionally, future research will also hopefully help in the development of legislation and policies that need to be implemented to hopefully prevent the frequency and severity of emergency room cases and guide public health and transportation ministries as to best practices. This legislation could take the form of mandatory helmet use laws, minimum requirements for riders, and so on. Physician advocates may encourage lawmakers to create marketing guidelines for this technology to help keep vulnerable patients safe since some e-scooter companies are advertising the use of e-scooters without protective equipment (32).

In conclusion, e-scooter technology is a new form of micro-mobility that has the potential to cause serious harm to Canadians, both from paediatric and adult populations. While there are news reports, as well as individual case studies and case series reports documenting patient demographics and injuries associated with this technology, there currently exist no formal systematic reviews or meta-analysis. While narrative reviews are useful in quickly and efficiently summarizing the evidence on this technology, a systematic review would help to summarize the state of evidence on e-scooters in a more comprehensive and objective way. Specifically, these reports are needed to help formally summarize the data that exists on specific injury types, prevalence, and severity. Furthermore, future studies should investigate the roles of alcohol use and lack of helmet use can make on injury prevention and mitigation. As e-scooter use increases throughout Ontario, this data will be paramount in keeping Canadians informed and safe.

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