Descriptive Analysis of Cyclist Dooring Events Using Data from the National Electronic Injury Surveillance System (NEISS)

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Abstract Dooring events in which a moving vulnerable road user, such as a cyclist, impacts an open vehicle door represent a well-known collision type, though little is known about the associated injury risk. This study leveraged 10 years of data from the National Electronic Injury Surveillance System to characterise cyclist injuries associated with dooring events. After filtering out cases which did not include explicit mention of a collision with an open vehicle door using the narrative, 644 cases were identified, representative of 17,156 injured persons presenting to emergency departments in the United States. Narratives were reviewed to determine helmet usage, cyclist fall status, and additional context for the coded injury diagnosis and body region. Superficial injuries were observed in nearly half of all events (48%), and fractures were noted in approximately 13% of all cases. Non-objective injury outcomes (complaints of pain only) occurred in 17.3% of events. While most events resulted in superficial injuries and/or did not require hospital admission, some serious or greater injuries were observed, either due to direct contact with the open vehicle door or subsequent contact with the ground or surrounding environment. This represents the first national estimate and investigation of dooring injuries in the United States.

Keywords Dooring, emergency department, injury mechanism, micromobility

I. INTRODUCTION

According to the National Highway Traffic Safety Administration (NHTSA), as of 2020, the estimated number of bicyclists killed in traffic collisions with motor vehicles in the United States had increased approximately 50% to 938 from its recorded low in 2010 [1]. It is further estimated that as many as 130,000 cyclists in the United States are injured annually [2].

While cyclist injuries as a result of collisions with moving motor vehicles have been well-researched in the literature [3-5], injuries and risks associated with dooring are not well-documented. Dooring describes an event wherein an oncoming cyclist collides with an open or opening car door. Most injury risk models only consider collisions with moving vehicles, which would exclude dooring events from analysis [4-5].

In general, dooring events may occur in one of four ways [6]. The cyclist may collide directly with an open vehicle door, which is often associated with a large impulse imparted onto the cyclist by the vehicle for a dooring event. These events may not necessarily result in a cyclist falling off their bicycle, as the open door and vehicle may serve to arrest continued forward motion. Alternatively, the cyclist may collide with an opening car door as they pass by the vehicle or may only contact the vehicle with their handlebars. Both of these scenarios would be associated with a lesser initial crash impulse but would tend to increase cyclist instability and falls to the ground would be expected. Lastly, a cyclist might observe an open/opening door or anticipate an opening door in their path and attempt to avoid a collision with the open door. This cyclist may then experience a collision event with another vehicle or, depending on the extent of the avoidance manoeuvre, experience a fall to the ground. It should be noted that the potential for a fall to the ground and conflict and/or collision with other vehicles or roadway users exists in any dooring event.

Dooring has been documented as a unique injury-causing collision configuration for cyclists [7-11]. Estimates from a variety of data sources from around the world indicate that dooring may occur in 3% to 10% of all cyclist traffic collisions resulting in injuries [12-14]. Data from a survey of German cyclists indicate that 6% had experienced a dooring event [15]. Work conducted as part of the Proactive Safety for Pedestrians and Cyclists

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(PROSPECT) project in Europe highlighted the importance of better understanding dooring events [16-17].

Given that cyclist collisions are underreported in police-report data [18-20], researchers developed a survey to better understand the true nature of cyclist collisions [21-22]. The results of this survey indicated that approximately 85% of all cyclist collisions in Ireland were not reported to the police. All injuries were categorised as either Minor or Serious based on the European Commission's definition of injury severity. Injuries to the upper and lower extremities were most commonly reported in this dataset [21]. In a follow-up study investigating the collision typology for these survey responses, it was reported that dooring occurred in 12% of all cases, with minor injuries observed in the majority of events [22]. Further, only 22% of the dooring events were reported to the police [22].

While these studies have been crucial in better understanding the incidence of the problem of dooring, it is also necessary to understand the specific injuries associated with this subset of cyclist collision events. These studies have also primarily focused on collisions outside of the United States, where the prevalence and severity of dooring may vary. Accordingly, the objective of this study was to leverage data from the National Electronic Injury Surveillance (NEISS) database to characterise cyclist injuries associated with dooring events which resulted in presentation to an emergency department in the United States. This study is only intended to further our understanding of injuries associated with dooring events and does not explore any efforts to mitigate the frequency of dooring events or the effect of those efforts.

II. METHODS

Data Source

NEISS is a probability sample of 100 hospitals in the United States and its territories that have at least six beds and an emergency department [23-25]. The sample is stratified based on size of the emergency department and geographic location of the hospital: small, medium, large, and very large, with an additional stratum for children's hospitals. NEISS cases are weighted by the inverse probability of selection in order to generate nationally representative estimates. Operated by the Consumer Product Safety Commission (CPSC), the primary goal of NEISS is to *collect data on consumer product-related injuries occurring in the United States* [23]. All cases presenting at these hospitals for treatment related to a consumer product-related injury are included in NEISS. NEISS has been used extensively to describe and categorise injuries for a variety of products, from fireworks and e-cigarettes to micromobility devices like hoverboards, scooters, and e-scooters. [26-32]. Bicycles are considered a consumer product and are included in NEISS [23][33].

The NEISS database is publicly available. NEISS collects data related to patient demographics (age, sex, race or ethnicity), incident information (consumer product involved, location, involvement of fire/alcohol/drugs), and injury information (case narrative, involved body part and a generalised diagnosis code) [23][33].

For this study, the database was queried for all cases from 2012-2021 involving bicycles (product code 5040). Other micromobility products were also pulled in this initial query, as potential for dooring events with motor vehicles is not restricted to cyclists. To that end, product codes for skateboards (1333, 5025, 5042), roller skates (3216), and scooters (5022, 5023, 5024) were included. For the remainder of this paper, use of the term *cyclist* is inclusive of riders of these other means of transport. This query resulted in 181,622 cases over the 10-year period.

An automated filter was applied to restrict the cases to only those which were related to dooring. This was achieved by searching the case narrative text for *door* and a motor vehicle related term, e.g., car, truck, van, bus, SUV, automobile, vehicle, and common misspellings. This filter reduced the dataset to 816 cases (Figure 1). Next, cases which did not have sufficient injury information were excluded from the dataset. These consisted of cases for which an injured body region was noted without further specification as to the injury or instances of non-specified head trauma. A total of 21 cases met these criteria, further reducing the dataset to 795 cases. Upon narrative review, 32 cases were identified as not being dooring events. Examples include narratives which included *outdoor* or *indoor* or other non-dooring events, such as having a door closed on the hand or colliding with a vehicle moving in traffic. Lastly, 119 cases were removed after narrative review for not having explicit mention in the narrative text about an open vehicle door (Figure 1). This represented a conservative analytical approach to ensure that all included cases represented situations of definitive dooring and avoided narrative ambiguity. With these filtering criteria applied, the final dataset consisted of 644 dooring cases. With the provided NEISS weights, these 644 cases represent 17,156 total injured persons as a result of dooring. Unless otherwise noted, all percentages and counts refer to these weighted numbers.

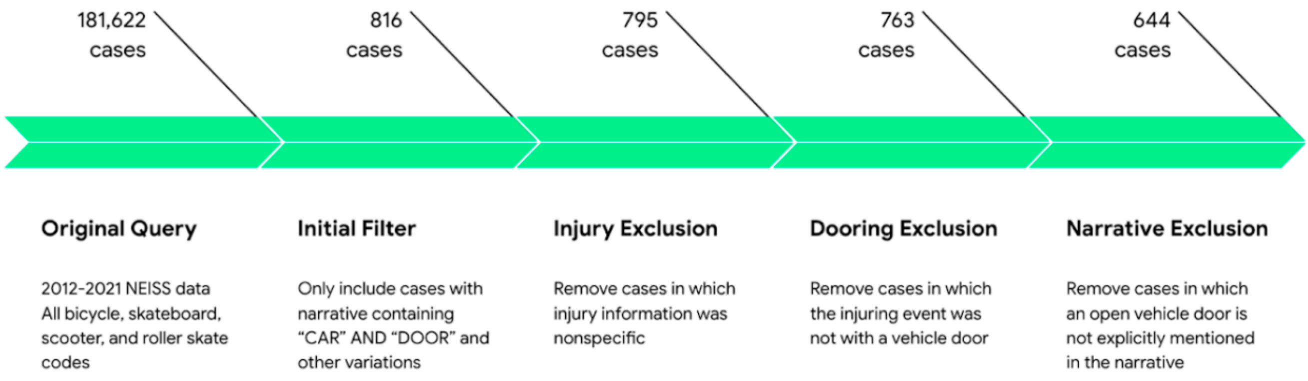

Fig 1. Summary of query and exclusion criteria to generate final sample for data analysis

Case Review

All cases were thoroughly reviewed to extract as much detail as possible. Using the body part and diagnosis coding in conjunction with the case narrative, all cases were reduced to a single body region category and injury category based on the most serious injury for that event. Body regions and injury severity were defined in the same manner as the 2015 revision of the Abbreviated Injury Scale (AIS), with the exception that the neck region as defined in this study combined both neck and cervical spine injuries [34]. Regions included: Head, Face, Neck, Thorax, Abdomen, Thoracic Spine, Lumbar Spine, Pelvis, Upper Extremities, and Lower Extremities. Any case in which multiple body regions were involved and the identified injuries were of the same severity and nature were classified as Multiple. Simplified injury classifications were developed that encompassed the range of injuries observed in this dataset (Table I).

The NEISS database does not provide AIS coding for the cases. Rather than using explicit AIS coding, the injury codes, narrative description, and patient disposition were used in combination to define injury severity as Pain, Minor, Moderate, and Serious or greater by matching the described injury to its most likely AIS coding. In general, the minor, moderate, and serious designations correspond to AIS1, AIS2, and AIS3 injuries as defined in the AIS coding manual [34].

TABLE I

SIMPLIFIED INJURY CLASSIFICATION SCHEME EMPLOYED IN THIS STUDY. MOST INJURIES IN THE *OTHER INTERNAL* CATEGORY WERE ASSOCIATED WITH HIGHER SEVERITY INJURIES

Injury Classification	Description
Pain	Cases in which the only diagnosis or description of injury indicated pain
Superficial	Cases involving abrasions, contusions, or lacerations
Sprain/strain	Cases involving muscle/ligament strain/sprain
Fracture	Cases involving bone fracture
Other Internal	Cases involving all other internal injuries, e.g., concussion, subdural haemorrhage, dislocation, pneumothorax

Narratives were also reviewed to investigate helmet usage and to determine whether the individual fell as a result of the event. All cases with definitive helmet status (helmeted/unhelmeted) were assigned accordingly, with all other cases coded as unknown. Examples of definitive helmet use included *helmeted*, *w/ helmet*, and *+ helmet*, with common misspellings also investigated. Definitive non-helmet use included similar strings, e.g., *unhelmeted*, *- helmet*, *w/o helmet*). Fall status was defined similarly, in that cases where the narrative clearly stated the cyclist fell were identified as falls. Cases which did not mention fall status or had any ambiguity in fall status were classified as unknown. Lastly, the narratives were reviewed to identify potential sources of injury based on what the cyclist contacted during their collision event. Options included vehicle door, the ground, or other vehicles travelling in the roadway. Previous research has shown that leveraging the free-text narrative field in NEISS offers insight into additional variables and questions of interest than what is reported in the coded fields [35].

III. RESULTS

Over the 10-year period from 2012 to the end of 2021, the NEISS database captured 644 cases representing 17,156 total injured persons as a result of dooring. This represents approximately 1,700 persons per year presenting for treatment at an emergency department for injuries sustained during dooring events. All percentages presented below represent the weighted cases.

Superficial injuries, like abrasions, contusions, and lacerations, represented almost half (~48%) of all injuries for which individuals sought treatment subsequent to a dooring event (Figure 2). Fractures were observed in about 13% of all cases. Of note, non-objective injury outcomes, i.e., complaints of pain only, occurred in ~17% of all cases in this dataset involving presentation to emergency departments.

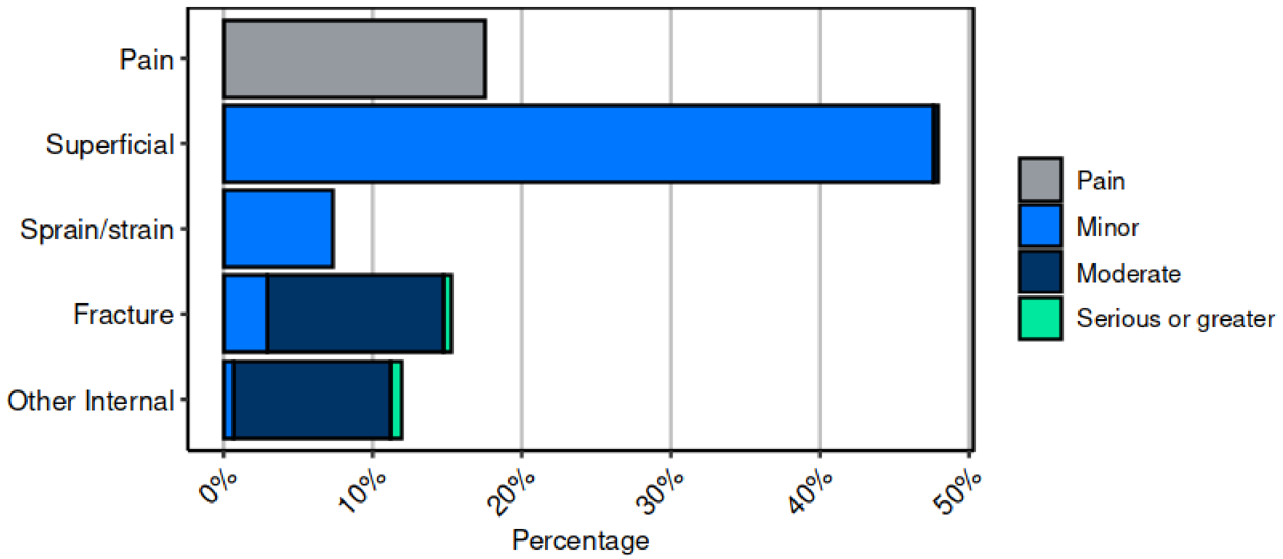

Fig 2. Summary of injuries by injury type and severity. Each case was assigned a single injury category based on the highest severity injury reported. Percentage represents weighted cases.

Among body regions, the upper extremities were most commonly the single region of most severe injury (~36% of all cases), followed by the lower extremities and head, at approximately 15% and 12%, respectively (Figure 3). In nearly 20% of cases, individuals sustained injuries of the same nature and severity to multiple body regions, e.g., contusions to the hand and face.

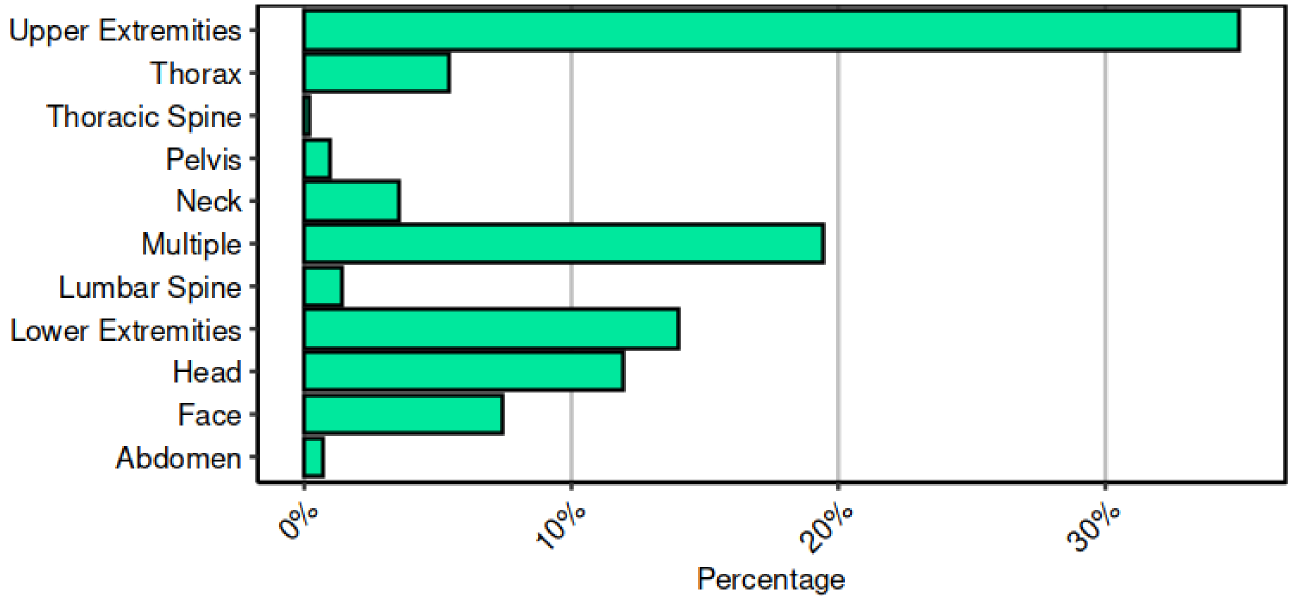

Fig 3. Summary of injuries by body region. This considers all injuries in the dataset across the various severity levels. Percentage represents weighted cases.

Injuries were also stratified by body region to identify trends. Generalised whole body pain or pain across multiple regions represented the majority of cases in which pain was the only diagnosis (Figure 4). Fractures to the upper extremities represented approximately 10% of all cases. Superficial injuries were most commonly observed in the upper or lower extremities and the face, or across multiple body regions. The vast majority of head injuries were classified as *Other Internal*.

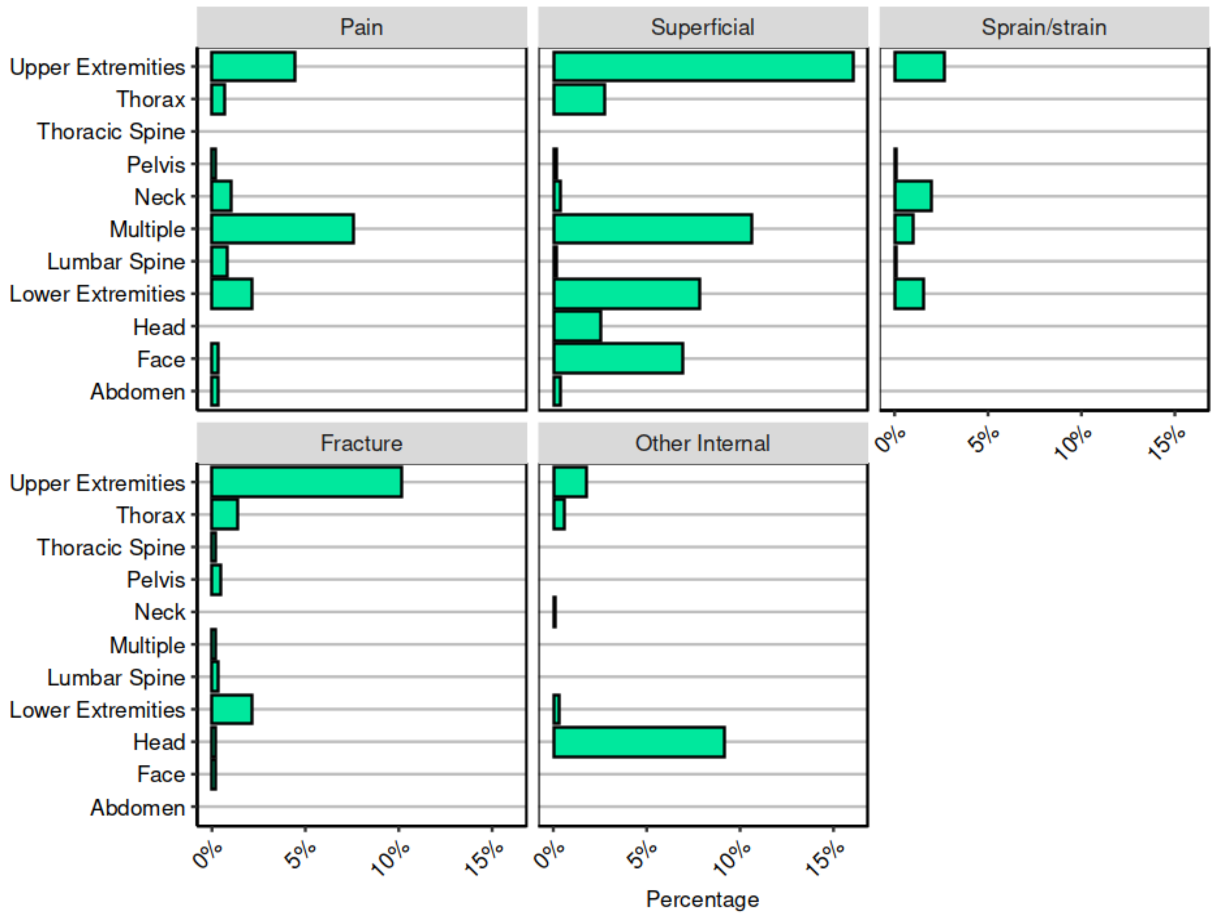

Fig 4. Summary of injured body region by injury classification. This considers all injuries in the dataset across the various severity levels (sum of all individual bars equal to 100%). Percentage represents weighted cases.

Definitive notation of cyclists falling was obtained from more than half of all cases (56.6%), with only a single case explicitly stating that the cyclist did not fall. Of the 14 total cases which resulted in serious or greater severity injuries, 11 (1% of weighted cases) involved a fall to the ground. This represented a threefold increase relative to unknown fall status; for all other injury severity classifications, the proportion of injuries was always greater for cases involving falls, though not as marked a difference as observed for the serious or greater injuries.

Definitive cyclist helmet status (helmeted/unhelmeted) was determined in approximately 25% of all cases, with helmet use observed twice as often as unhelmeted status. Among cases with a head injury, all cases with definitive helmet status were associated with moderate or serious or greater injury severity (Figure 5). Further, the number of unhelmeted (139 weighted cases) and helmeted (124 weighted cases) events with head injuries were similar. An unadjusted odds ratio was calculated relating the odds of sustaining a head injury with helmet use compared to being unhelmeted. In this dataset, helmeted cyclists had a 58% reduction in the odds of sustaining a head injury (odds ratio: 0.42, 95% confidence interval: 0.33-0.54) compared to unhelmeted riders.

For the events included in this dataset, 604 cases (94% of weighted cases) resulted in patients not being admitted into the hospital. Of the remaining 40 cases which resulted in hospital admission, 30 were associated with moderate or serious or greater severity. Interestingly, three cases which were classified as serious or greater in severity did not result in hospital admission. Serious or greater injury outcomes were observed in only 1.3% of all cases (Figure 5). Minor injuries were observed approximately three times as often as moderate injuries.

Contact with the open vehicle door and subsequently the ground occurred in approximately 56% of all events in this dataset. Isolated contact with the open vehicle door was observed in approximately 43% of all events. The remaining events either involved the ground exclusively (0.4% of weighted cases) or another vehicle (0.7% of weighted cases).

Approximately 80% of cases involved males. This proportion roughly held between sexes across injury severities and classification. Adults (aged 18-65) comprised 92% of the dataset, with children below 18 years old (~6%) and the elderly (older than 65 years old) being less represented in the data. Injury outcome and severity were not observed to vary by age group.

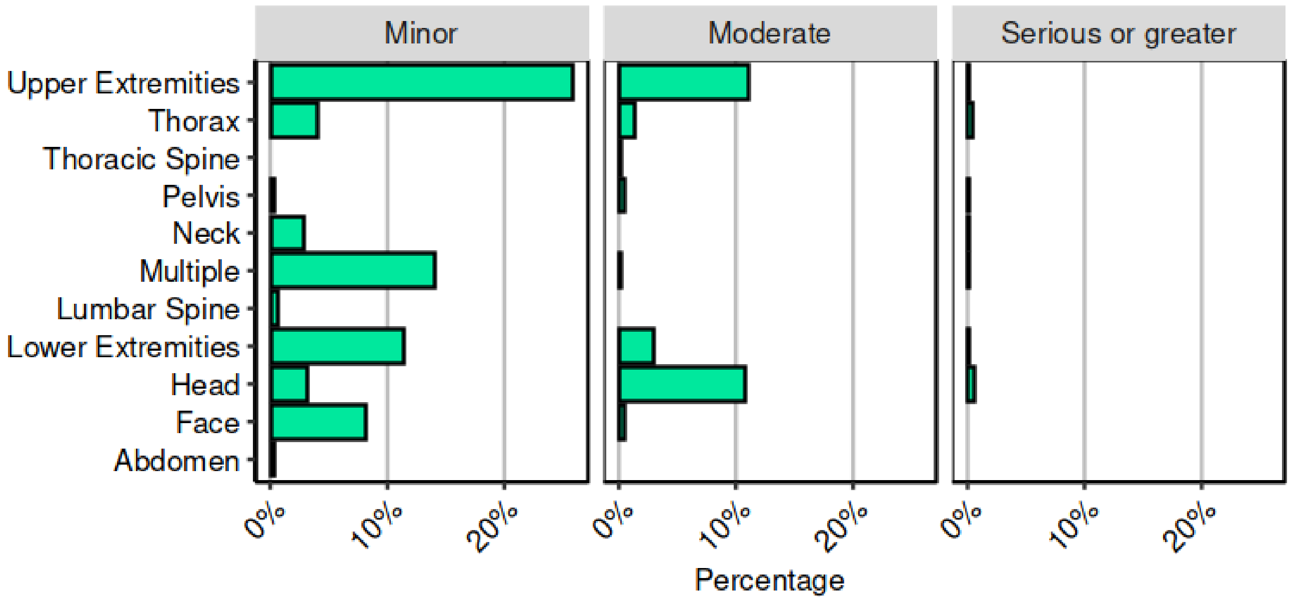

Fig 5. Summary of injured body region by injury severity. The *Pain* classification is not included here as it is already presented in the first panel of Figure 4. Percentage represents weighted cases.

IV. DISCUSSION

This study presents a detailed review of cyclist injury outcomes associated with dooring events for individuals who presented to an emergency department. Previous research has shown that hospitals are more likely to have record of collisions involving cyclists than police-reported data [19-20]. Building on existing literature that has discussed the prevalence of dooring events, this study provides a more in-depth analysis of specific injuries sustained during dooring events. These findings highlight the potential for serious injury during dooring events and may serve as a foundation for testing to better understand how these injuries occur.

Individual case narrative review indicated that the various dooring mechanisms outlined in the introduction were observed in this dataset. While there was not explicit mention of fall status in each case, 43% of events involved only engagement with the vehicle door during a collision. One narrative noted a cyclist *riding his bike when a car door opened and [patient] crashed into it*, resulting in facial lacerations and abrasions. Injuries isolated to the upper extremities represented the most commonly affected body region in this dataset, accounting for over a third of all weighted cases and approximately 63% of all fractures. A representative narrative described a patient who was riding a scooter and *his hand struck an open door of a parked car*, resulting in a fractured finger. Falling to the ground either due to direct contact with an open or opening door or to avoid an open door can also create injurious outcomes, as evidenced by some of the cases in this dataset. One individual *was biking when a car door open[ed], fell into street and car drove over [left upper extremity]*, resulting in a dislocation injury. Another narrative noted a helmeted rider *swerved bike to avoid an opening car door and fell*, resulting in subdural and subarachnoid haemorrhages. These representative examples highlight the variety of manners in which cyclists may engage with a vehicle and the roadway environment as a result of a dooring event, and the variability of resulting injuries and severities.

Over 90% of the dooring events for which patients sought treatment at an emergency department did not result in admission to the hospital. Approximately two-thirds of all events involved either no objective diagnosis of injury (~17%) or a superficial injury, such as an abrasion, contusion, or laceration (~48%). These events have the potential to not be reported to the police and underscore the importance of considering additional data sources in order to develop an overall understanding of specific injury-causing scenarios [19-20]. Consistent with the self-reported injury survey data presented by [21], the upper and lower extremities were the most commonly injured body regions during dooring events [21]. In this dataset, males represented 80% of all cases involving dooring events. This disproportionate divide across sex is consistent with nationally-reported cyclist crash injury data across all collision configurations, where males experience injuries at a rate five times that of females [35].

Definitive helmet status within this dataset (~25%) was higher than what has previously been reported for cyclists in NEISS data (14%), though still not observed for most events [36]. National survey data collected in 2012 by the National Highway Traffic Safety Administration in the United States indicated that approximately 46% of cyclists never wore a helmet when riding their bicycle, with only 28% reporting always wearing a helmet [37]. A consumer-based survey carried out during the same timeframe revealed similar trends, with 29% of respondents stating they always wore a helmet and 56% reporting never wearing a helmet when riding their bicycle [38]. The calculated, unadjusted odds ratio for head injury and helmet use presented here (odds ratio: 0.42, 95% confidence interval: 0.33-0.54) is consistent with a previously-reported meta-analysis (odds ratio: 0.49, 95% confidence interval: 0.42-0.57) [39]. It should be noted that the odds ratio presented in this study is affected by this dataset being censored in that it only considers those cyclists who sought treatment at an emergency department, and it would be expected that unhelmeted riders would be more likely to sustain a head injury necessitating a treatment at the emergency department.

While serious or greater injury outcomes as a result of dooring events were rarely observed in this dataset (only 1.3% of all weighted cases), understanding the nature of these injuries is important. The dooring events which resulted in serious or greater injury outcomes were associated with fractures or other internal injuries. This is consistent with what has previously been reported for dooring events [21]. Fractures were observed in five of the 14 events. Other internal injuries included various haematomata (epidural and subdural) and haemorrhages (subarachnoid and subdural) in the brain, pulmonary contusion, tracheal perforation, and pneumothorax. Each of the events involving other internal injuries resulted in hospital admission, while three of the five fractures did not include hospital admission. While in some cases the injury mechanism is clear, such as the tracheal perforation, for which the narrative stated that the individual *struck [neck] on an open car door*, other injuries as a result of blunt impact trauma may occur during the initial impact with the car door or subsequent ground or roadway environment contact. While the NEISS database does not provide information on crash kinematics, such as cyclist speed or crash configuration, which would be useful in relating injury outcomes to specific collision inputs, this analysis shows that dooring events represent a unique traffic conflict type which has the potential to result in serious injury outcomes. Additional work relating the oncoming speed of the cyclist and the geometry and/or kinematics of the collision with injury outcomes is necessary for further, refined evaluation of injury risk for dooring events.

There are several limitations to note regarding this study. First, the NEISS database is dependent on coordinators accurately and completely translating information from patient medical records into the NEISS database. Narrative information included in cases is often pulled from information provided by the patient and may be subject to limitations in specificity and/or reliability. Additionally, the NEISS case narrative is a text-based field with a character limit. The narrative field provides information of patient demographics, injury/diagnosis, and a description of the event. For all cases prior to 2019, only 142 characters could be included in the narrative section; from 2019 onward, up to 400 characters were allowed. The effect of this was mitigated through using only those cases which explicitly mentioned an open or opening car door in the case narrative. For all cases prior to 2019, only a single body part and diagnosis were coded, while a second body part and diagnosis code option were available from 2019 onward. The effect of this was mitigated by reviewing each case's narrative in combination with the diagnosis codes to ensure that injuries were appropriately handled and classified for analysis. Helmet status and fall status were not available for each event in this dataset. Not surprisingly, helmet status was most commonly available in the narrative for cases involving a head injury. As mentioned above, the NEISS database does not provide any collision-specific information, i.e., speed and/or orientation of the cyclist, what body regions engaged with the door or ground, which limits the ability of researchers to relate collisions to injury outcomes. Further, inclusion in the NEISS database is dependent on presentation to an emergency department. It is likely that some more minor events or events with only pain and no other objective medical diagnosis have not been captured, where patients either did not present for any medical attention or went to their primary care physician or an urgent care facility. Nonetheless, these data provide a representative sample of dooring events in the United States for which individuals sought medical treatment in an emergency department, and the NEISS database is a valuable tool in gleaning insights and trends related to injuries in the United States.

V. CONCLUSIONS

This study evaluated the nature and extent of cyclist dooring events by leveraging injury data from a national surveillance system of United States emergency departments. This represents the first national estimate and investigation of dooring injuries in the United States. While most events in this dataset resulted in superficial injuries and/or did not require admission to a hospital, some serious or greater injuries were observed, either due to direct contact with the open vehicle door or subsequent contact with the ground or surrounding environment following initial engagement. Additional work relating the oncoming speed of the cyclist and the geometry and/or kinematics of the collision with injury outcomes may be helpful for further refining evaluation of injury risk for dooring events.

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