Trends and Costs of Non-Fatal Micromobility-Related Injuries Treated in Emergency Departments in Rhode Island, 2016–2021

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ABSTRACT

BACKGROUND: Micromobility devices like e-scooters have become popular for short trips. Providence, Rhode Island, introduced these devices in 2018. We examine non-fatal injury trends and ED care costs for micromobility-related injuries in Rhode Island (RI) from 2016 to 2021.

METHODS: Data were obtained from the Healthcare Cost and Utilization Project (HCUP) and the RI State ED Databases (SEDD). Using ICD-10 codes, we identified micromobility-related injuries. The analysis spanned two waves: pre-implementation (2016–2018) and post-implementation (2019–2021). Poisson regression was performed on age-adjusted rates of micromobility injuries to evaluate change over time.

RESULTS: From 2016 to 2021, micromobility-related ED visits rose 600%. Bicycle injuries decreased by 20%, while pedestrian and motor vehicle injuries increased by 9% and 13%, respectively.

CONCLUSION: The dramatic rise in micromobility-related injuries reflects their growing usage and the associated risks. Micromobility offers benefits and challenges for cities. Safety measures are crucial for their safe, sustainable use.

KEYWORDS: Micromobility; e-scooters; emergency department; cost of care

INTRODUCTION

Micromobility devices, such as e-scooters, e-bikes, and self-balancing vehicles, have gained popularity in American cities. They provide environmental, social, and economic benefits. However, there are unintended consequences. Multiple studies have documented e-scooter-related injuries following the introduction of rental programs across various metropolitan areas, including Los Angeles, California,[1–3] Dallas, Texas,[3] Austin, Texas,[4] St. Louis, Missouri, [5] Atlanta, Georgia,[6] and Washington, DC.[7] While these studies focused on injury rates post-implementation, only two studies in the United States have examined micromobility injuries pre- and post-implementation of micromobility rental programs. One found that implementing an urban rental program in Salt Lake City was associated with a substantial increase in e-scooter injuries, from eight in 2017 to 50 in 2018.[8] Another also found a significant increase in e-scooter-related injuries in Indianapolis, IN, following the implementation of a rental program.[9]

As of Fall 2018, Providence, Rhode Island, adopted micromobility devices as sustainable, low-carbon transportation for short trips.[10] Standard injury surveillance is unavailable for micromobility-related injuries in RI. We describe non-fatal injuries presenting to emergency departments (ED) in the State of Rhode Island over five years (2016–2021) and examine trends before and after the introduction of micromobility rentals in Providence. We also estimate ED-care costs for these injuries. Based on evidence from other cities, we hypothesized that implementing a micromobility rental program increased all roadway injuries in general (pedestrian, motor vehicle, bicycle, and micromobility) after implementation. We also hypothesized that micromobility injuries specifically increased after the implementation of the rental program.

METHODOLOGY

Data collection process

We used data from the Healthcare Cost and Utilization Project (HCUP), sponsored by the Agency for Healthcare Research and Quality, specifically from the Rhode Island State Department Databases (SEDD), including records from hospital-affiliated EDs for non-hospitalized visits.

ICD-10 codes from the National Center for Injury Prevention and Control's External Cause-of-Injury Framework (NCIPC-ECIF) were used to select external causes that injured bicyclists, pedestrians, and motor-vehicle drivers/occupants involved in crashes.[11] Because that framework, published in 2019, does not contain micromobility, we used the National Highway Traffic Safety Administration's National Emergency Medical Services Information System (NEMSIS) Version 3 case definitions to identify micromobility injuries.[12]

Measures

ED costs were calculated by multiplying the encounter charge by each hospital's cost-to-charge ratio. For ease of comparison and to account for inflation, all cost data were standardized to December 2021 dollars, using data from the Federal Reserve on the Consumer Price Index (CPI) for all medical care in U.S. cities.[13]

Statistical analysis

Descriptive analyses were performed to describe the patient population, examine the distribution of roadway injuries (pedestrian, bicycle, motor vehicle traffic [MVT], and micromobility), and explore encounter costs for ED visits. Poisson regression was utilized to compare the age-adjusted roadway and micromobility injury rates by sex in the three years before the micromobility accessibility implementation in Rhode Island with the three years after the implementation. The natural log of the sex-specific standard population was utilized as the model's offset term. Statistical analysis was conducted using SAS.14

RESULTS

Trends in ED visits for injuries to multiple road-user types in RI

There was a substantial increase in micromobility-related cases over the study period (**Figure 1**). Specifically, cases escalated from 14 in 2016 to 98 in 2021, an approximate 600% increase. In contrast to micromobility, bicycle-related injuries decreased by approximately 20%, from 319 cases in 2016 to 254 cases in 2021. Pedestrian-related cases, on the other hand, showed a slight increase of 9.18%, rising from 403 cases in 2016 to 440 in 2021. Non-fatal injuries related to MVT also increased 13.41%, from 328 in 2016 to 372 in 2021.

The analysis of non-fatal transportation injury rates in Rhode Island reveals distinct age-adjusted trends over recent years for micromobility, bicycle, pedestrian, and motor vehicle traffic injuries by year and sex. Micromobility rates fluctuated between 2016 and 2019 and dramatically increased in 2020 and 2021. Bicycle injuries were relatively stable from 2016 to 2019, followed by an increase in 2020 and a decrease in 2021. Pedestrian injury rates increased between 2016 and 2018. MVT injuries were relatively stable from 2016 to 2018, followed by an increase from 2019 to 2020 and a decrease in 2021.

There was a slight increase in micromobility injury rates for female patients between 2016 and 2019, followed by a dramatic increase in 2020 and 2021. For female patients, there was a progressive decrease in pedestrian injury rates from 2019 to 2021. For male patients, pedestrian injury rates increased from 2016 to 2017 and remained stable for the remainder of the time. Sex differences for bicycle and MVT injuries were not observed.

Cost Estimation

Between 2016 and 2021, there was a gradual increase in the total encounter costs related to roadway injuries, pedestrian injuries, and MVT injuries, and a sharp increase in micromobility-related injuries (**Figure 2**). From 2016 to 2019, micromobility injuries resulted in a cost of approximately $10,000 per year, followed by an increase to $29,792.64 in 2020 and $80,487.37 in 2021. From 2016–2019, pedestrian-related injuries increased in total cost yearly from $366,382.51 in 2016 to $634,129.25 in 2019, followed by a decrease to $581,857.60 in 2020 and a slight increase to $602,331.23 in 2021. MVT-related injuries costs were stable between 2016–2017 ($367,726.04 in 2016 and $367,107.88 in 2017), followed by an increase from 2018 ($408,692.79) to 2020 ($595,680.94) and a slight decrease in 2021 ($569,680.94). The total cost for all roadway injuries increased yearly from $992,925.81 in 2016 to $1,479,120.70 in 2021. Bicycle-related injury costs remained relatively stable throughout the six years of data analysis, hovering between $200,000 and $250,000.

Figure 1. Unadjusted Trends by Year for Micro, Pedestrian, Bicycle, and MVT cases.

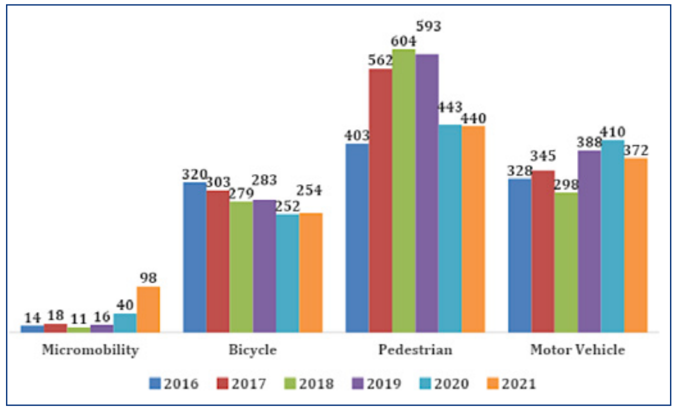
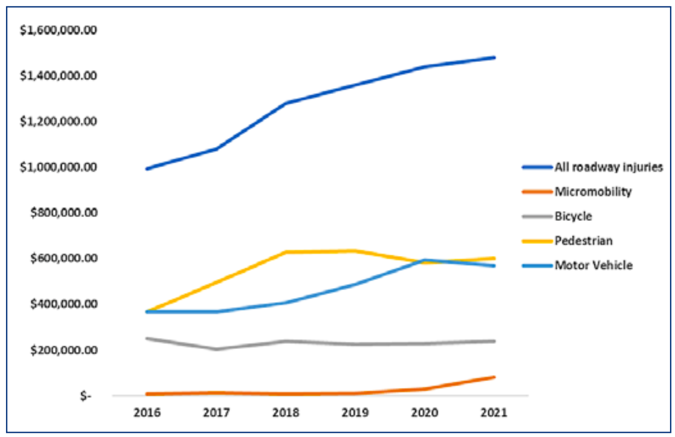


Figure 2. Encounter cost trends for all roadway injuries, including micromobility, bicycle, pedestrian, and motor vehicle crashes.



Impact of Micromobility Implementation on All Roadway Injury Rates

The age-adjusted Poisson regression analysis results for roadway injuries (i.e., all mode types, including micromobility, bicycle, pedestrian, and motor vehicle) are shown in **Table 1**. The roadway-related injuries were significantly different over time ($p<.001$) and by sex ($p<.001$) but not significantly different for the sex by time interaction ($p=0.97$). Roadway injuries in the post-period had a rate 1.25 times greater than

Table 1. Age-Adjusted Poisson Regression Analysis Results for Roadway Injuries Across All Modes of Transportation

	Estimate (95% CI)
Intercept	0.00026 (0.00023, 0.00028)
Implementation (Post v. Ref: Pre)	1.25 (1.16, 1.34)
Sex (Male v. Ref: Female)	3.49 (3.24, 3.76)
Implementation * Sex[a]	—
Post and Female v. Ref: Pre and Female	1.25 (1.1, 1.42)
Post and Male v. Ref: Pre and Male	1.25 (1.17, 1.34)

[a] Interaction between implementation and sex was not significantly different (p=0.97)
Abbreviations: CI = Confidence Interval; Ref = Reference Group.

Table 2. Age-Adjusted Poisson Regression Analysis of the Impact of Micromobility Implementation on Injuries, Including Sex and Sex-Implementation Interaction.

	Estimate (95% CI)
Intercept	0.0000054 (0.0000028, 0.00001)
Implementation (Post v. Ref: Pre)	5.08 (3.2, 8.08)
Sex (Male v. Ref: Female)	1.45 (0.91, 2.3)
Implementation * Sex [a]	—
Post and Female v. Ref: Pre and Female	5.81 (2.84, 11.89)
Post and Male v. Ref: Pre and Male	4.45 (2.48, 8.0)

[a] Interaction between implementation and sex was not significantly different (p=0.57)
Abbreviations: CI = Confidence Interval; Ref = Reference Group.

that of the pre-period (95% CI: 1.16, 1.34). Male patients had a rate of 3.49 times greater than female patients for roadway injuries (95% CI: 3.24, 3.76). However, the rate of change over time did not differ significantly by sex as both male and female patients sustained a 25% increase in roadway injuries from pre to post.

Subset Analysis of Micromobility Injuries

Demographics: We found 197 individuals sustained micromobility injuries over the six years: 103 men (52.3%; M= 31.4 years; SD= 21.2) and 94 women (47.7%; M= 34 years; SD= 22.91). Of these, 129 (65.5%) were White, 27 (13.7%) Black, 22 (11.2%) Latino, and 16 (8.1%) Asian or classified as Other. Of the 197, 34 (17.3%) resided outside of RI, 53 (26.9%) lived in Providence, and 110 (55.8%) lived in other cities in RI. Among patients with micromobility injuries, 78 were insured by private insurance (39.6%), 78 by Medicaid (39.6%), 25 by Medicare (12.7%), 15 (7.6%) were either self-pay or other, and one had missing information.

Impact of E-Scooter Implementation on Micromobility Injury Rates: An age-adjusted Poisson regression analysis assessed the implementation's impact on micromobility injuries, accounting for sex and the interaction between implementation and sex (**Table 2**). Micromobility injury rates were significantly different by implementation period (p< .001) but not by sex (p=0.25). The interaction of sex and implementation period was nonsignificant (p=.57). Micromobility injury rates were 5.08 times higher post-implementation than pre-implementation (95% CI: 3.2, 8.08). Among female patients, the micromobility injury rates were 5.81 times higher in the post-implementation period than in pre-implementation (95% CI: 2.84, 11.89). Male patients' micromobility injury rates were 4.45 times higher post-implementation compared to pre-implementation (95% CI: 2.48, 8.0).

DISCUSSION

All Roadway Injuries

Examining non-fatal transportation injuries treated in Rhode Island EDs from 2016 to 2021 reveals mixed patterns. Although the unadjusted number of bicycle injuries decreased by 20%, pedestrian injuries showed a slight increase of 9%, and motor vehicle injuries increased by 13%. The steep 600% increase in micromobility injuries over five years, mirroring trends in other cities, underscores the urgent need for measures to control and prevent these injuries.

The total cost of all roadway injuries exhibited a steady annual rise, escalating from $992,925.81 in 2016 to $1,479,120.70 in 2021. Between 2016 and 2021, there was a consistent upward trend in pedestrian and motor vehicle traffic (MVT) injuries, with occasional variations. The total cost of pedestrian-related injuries peaked in 2019, amounting to $634,129.25. That was followed by a reduction in 2020, maybe due to lower pedestrian activity during lockdowns imposed by the pandemic. In 2020, the expenses associated with MVT-related injuries peaked at $595,680.94, following a similar trend.

Over six years, the expenses associated with bicycle-related injuries remained rather stable, ranging from $200,000 to $250,000 yearly. Possible reasons for this phenomenon include more skilled riders, successful initiatives to educate the public about riding safely, a cycling infrastructure that continues to improve, or a demographic shift where previous bicycle riders have switched to e-scooters. The rapid adoption of micromobility, increased use during COVID-19, lack of safety regulations and infrastructure related to micromobility in Rhode Island, and user inexperience may all contribute to the surge in injuries and costs. While auto insurance would cover the costs when a motor vehicle driver was involved in hitting a micromobility user, we must still consider the financial burden on those who sustain injuries and the need to implement preventative measures to reduce these costs.

We tested whether introducing micromobility rental devices in Providence, RI, was associated with increased injuries for all roadway users in Rhode Island and, if so, whether the increases were the same for men and women. We found that the age-adjusted roadway injury rates increased by 25%

for both men and women after implementing the micromobility rental program. Before the introduction of micromobility rental devices were introduced, men already had a substantially greater rate of roadway injuries compared to women, with rates approximately 3.5 times higher.

Sub-Analysis of Micromobility Injuries

The reasons for the noticeable increase in injury rates post-implementation are not fully understood, but similar patterns have been observed in cities. Many cities lack the necessary infrastructure for alternative modes of transportation, as their systems are designed for motor vehicles.[15] This poses a significant risk to micromobility users due to the presence of cars.[16] Varying local regulations regarding micromobility devices creates confusion, making it difficult for users to know whether to operate them on sidewalks or roads, increasing the risk of injury.[16] More research is needed to determine if these factors contribute to increased injuries in Rhode Island.

The demographic data obtained from the subset of micromobility injuries offers significant insights into the traits of individuals impacted by this rising issue in public health. Our findings indicate that individuals in their early to mid-thirties are the primary individuals experiencing injuries. Other studies found median ages of 30 to 40.[2,4,17-19] The nearly equal split of injuries between males and females suggests micromobility risks are not significantly influenced by sex.

Most of the patients in our study were White (65%), reflecting Rhode Island's overall demographic composition, where the White (non-Hispanic) group made up 69.9% of the population in 2022. However, the Hispanic/Latino population, which grew to 17.6% in Rhode Island in 2022,[20] is underrepresented in our data, where only 11% of the injured were Latino. This discrepancy may arise from various factors. One is a potential misclassification by hospital staff if they visually assess and record patients' race. Another is the historical barriers to seeking medical treatment faced by non-White individuals. It is also possible that Latinos are not as likely to use micromobility as Whites since some neighborhoods have limited access to micromobility rentals, but further research is necessary to explore how diverse groups are represented in the data related to micromobility injuries and utilization.

Recommendations for Injury Prevention

Decades of experience in motor vehicle safety in the U.S. have led to significant improvements and ongoing funding to reduce motor vehicle injuries and fatalities. In contrast, micromobility is a relatively new area with rapidly increasing usage. Given the increase in micromobility injuries, RI might benefit from developing safety standards, targeted road safety interventions, enhancing data collection and surveillance, and reexamining micromobility regulations.

Other cities have addressed micromobility safety proactively. For example, Los Angeles collects extensive data from micromobility operators to understand ridership patterns and safety issues.[21] They also impose fines for non-compliance and have a reporting system for violations.[22] While determining if these interventions improve safety is beyond this study's scope, cities are actively addressing the issue. In contrast, RI's steps to address micromobility safety are unknown. As of July 2024, our review of websites for RI's 10 largest cities found little information regarding this issue.

By learning from other cities, Rhode Island can tailor best practices to local needs. Implementing micromobility lanes, enforcing speed limits, enhancing rider education, and improving data collection and surveillance may help mitigate risks. Collaboration with city planners, public health officials, and transportation agencies is crucial to developing effective strategies.

Limitations

Although our findings suggest concerning trends, they should be interpreted cautiously as several limitations exist. For example, using ICD 10 codes may misidentify or underreport micromobility injuries, mainly because these types of injuries are not thoroughly covered in the NCIPC-ECIF (2019) framework we used. In addition, our reliance on ED data may only capture some injury cases, missing those treated in other outpatient settings. Furthermore, our sample size was small, limiting the statistical power. A larger sample size is needed to support these findings. Finally, we could not determine whether and to what extent operator inexperience, infrastructure in need of repair (e.g., roadway potholes), and limited infrastructure (e.g., absence of protected lanes) played a role in injury occurrence. Given our limited data, we suggest ongoing monitoring of this injury mechanism and further research to better define micromobility-related injury control strategies.

CONCLUSION

The rise in micromobility-related injuries in RI highlights the need for ongoing surveillance to determine if the trend will persist. Gathering exposure data on micromobility riders will also be important for identifying high-risk groups that may benefit from targeted interventions. Researching these incidents' circumstances and environmental factors can help develop policies to promote safe micromobility use. While micromobility may offer convenience and environmental sustainability benefits, the associated risks cannot be ignored.

References

1. Bloom MB, Noorzad A, Lin C, et al. Standing electric scooter injuries: Impact on a community. *Am J Surg*. 2021;221(1):227-232. doi:10.1016/j.amjsurg.2020.07.020
2. C. Ishmael, Peter P. Hsiue, S. Zoller, et al. An Early Look at Operative Orthopaedic Injuries Associated with Electric Scooter Accidents: Bringing High-Energy Trauma to a Wider Audience. *J Bone Joint Surg Am*. Published online 2019.
3. Trivedi TK, Liu C, Antonio ALM, et al. Injuries Associated With Standing Electric Scooter Use. *JAMA Netw Open*. 2019;2(1):e187381. doi:10.1001/jamanetworkopen.2018.7381
4. English KC, Allen JR, Rix K, et al. The characteristics of dockless electric rental scooter-related injuries in a large U.S. city. *Traffic Inj Prev*. 2020;21(7):476-481. doi:10.1080/15389588.2020.1804059
5. Williams C, Bitter C, Lorber S, et al. Incidence of Emergency Department Visits for Electric Rental Scooters Using Detailed Ridership Data. *West J Emerg Med*. 2022;23(2):174-182. doi:10.5811/westjem.2021.6.51101
6. Vernon N, Maddu K, Hanna TN, Chahine A, Leonard CE, Johnson JO. Emergency department visits resulting from electric scooter use in a major southeast metropolitan area. *Emerg Radiol*. 2020;27(5):469-475. doi:10.1007/s10140-020-01783-4
7. Cicchino JB, Kulie PE, McCarthy ML. Injuries related to electric scooter and bicycle use in a Washington, DC, emergency department. *Traffic Inj Prev*. 2021;22(5):401-406. doi:10.1080/15389588.2021.1913280
8. Austin Badeau, Chad Carman, Michael Newman, J. Steenblik, Margaret Carlson, T. Madsen. Emergency department visits for electric scooter-related injuries after introduction of an urban rental program. *Am J Emerg Med*. Published online 2019.
9. Puzio TJ, Murphy PB, Gazzetta J, et al. The electric scooter: A surging new mode of transportation that comes with risk to riders. *Traffic Inj Prev*. 2020;21(2):175-178. doi:10.1080/15389588.2019.1709176
10. Shared Micromobility Program. City of Providence. 2024. Accessed August 3, 2024. https://www.providenceri.gov/planning/e-scooter-share-pilot-program/
11. Hedegaard H, Johnson RL, Garnett MF, Thomas KE. The International Classification of Diseases, 10th Revision, Clinical Modification (ICD-10-CM) External Cause-of-injury Framework for Categorizing Mechanism and Intent of Injury. *Natl Health Stat Rep*. 2019;(136):1-22.
12. National Highway Traffic Safety Administration. *National Emergency Medical Services Information System (NEMSIS) Version 3 Case Definitions*. National Highway Traffic Safety Administration; 2024.
13. U.S. Bureau of Labor Statistics. Consumer Price Index for All Urban Consumers: All Items in U.S. City Average. July 11, 2024. Accessed August 3, 2024. https://fred.stlouisfed.org/series/CPIAUCSL
14. SAS/STAT Software. Published online 2024.
15. DuPuis N, Griess J, Klein C. *Micromobility in Cities: A History and Policy Overview*.; 2019. https://www.nlc.org/sites/default/files/2019-04/CSAR_MicromobilityReport_FINAL.pdf
16. Institute for Transportation & Development Policy. *The City Shared and Autonomous Report: Micromobility*.; 2019. https://ssti.us/wp-content/uploads/sites/1303/2019/06/CSAR_MicromobilityReport_FINAL.pdf
17. Allen JR, English KC, Rix K, Brown CVR, Ziebell CM, Brown LH. 262 Epidemiology of Dockless Electric Rental Scooter Injuries. *Ann Emerg Med*. 2019;74(4):S103. doi:10.1016/j.annemergmed.2019.08.220
18. Gaeta T, Melville L. 266 Micro-Transit Injuries Admitted to an Urban Trauma Center: A Trauma Registry Review. *Ann Emerg Med*. 2023;82(4):S118-S119. doi:10.1016/j.annemergmed.2023.08.290
19. Gaeta T, Tall S, Melville L, Paris D. 268 Epidemiology of Urban Micro-Transit Injuries. *Ann Emerg Med*. 2023;82(4):S119. doi:10.1016/j.annemergmed.2023.08.292
20. U.S. Census Bureau. Rhode Island Profile. U.S. Census Bureau. 2022. Accessed August 8, 2024. https://data.census.gov/profile/Rhode_Island?g=040XX00US44
21. Thomas J. Micromobility Is Failing LA. Here's How to Fix It - dot.LA. dot.LA. November 19, 2021. Accessed August 3, 2024. https://dot.la/micromobility-los-angeles-2655762727.html
22. Goodman M. Prepare Yourself: Scooters Return to Dallas Streets This Week. D Magazine. May 23, 2023. Accessed July 30, 2024. https://www.dmagazine.com/frontburner/2023/05/prepare-yourself-scooters-return-to-dallas-streets-this-week/

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Updates

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Disclaimer

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