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Is e-cycling safer than e-scootering? Comparing injury risk across Europe when vehicle-type, location, exposure, usage, and ownership are controlled

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A B S T R A C T

Introduction: Recently, e-scooters have proliferated worldwide. Municipalities have been struggling with regulating e-scooters due to public concerns that the injuries from the new crashes outweigh the health and environmental benefits of micromobility use. Indeed, several studies have reported crash risk for e-scooters 4 to 10 times higher than that for bicycles. *Method:* We had unprecedented access to crash and exposure data collected in 2022 and 2023 from a rental service of e-scooters and e-bicycles in seven European cities. We conducted a retrospective cross-sectional study to compute injury rates and incidence-rate ratios for each city while directly controlling for geography, ownership, and exposure (measured in three different ways). *Results:* We analyzed 686 e-scooterist and 35 e-cyclist crashes. Injury rates were higher for e-cyclists than e-scooterists in most of the cities, for all exposure measures. Further, the incidence-rate ratios indicate that the injury risk was 2.5–10 times lower for e-scootering than e-cycling. *Conclusions:* E-scootering may not be riskier than cycling as several studies have claimed. In fact, by exploiting technology to control for location, exposure, ownership, and usage, our analysis shows that e-scooterists experience lower crash rates than e-cyclists. While our analysis has some limitations and cannot be considered conclusive evidence, taking location, usage, ownership, and high-resolution exposure into account—which our analysis did contrary to previous studies—is crucial for a more accurate comparison among (micromobility) transport modes. In general, our research suggests incorporating geofencing and GPS-derived exposure metrics in future safety assessments. *Practical application:* The results and methodologies presented in this paper may help urban planning of rental micromobility services within cities.

1. Introduction

Over the last few years, dockless shared electric scooters (e-scooters) have emerged as an attractive mode of transportation in urban landscapes (Department for Transport, 2022; National Association of City Transportation Officials, 2024). The rapid rise in micromobility-sharing services has raised concerns regarding safety and crash risks. Despite regulatory frameworks often categorizing e-scooters as bicycles, the dynamics of e-scooter operation significantly diverge from those of bicycles (Dozza et al., 2023; Li et al., 2023; Terranova et al., 2024), and concerns about this new mode of transport being less safe than cycling may be legitimate. Indeed, empirical data from studies conducted in Oslo, Copenhagen, and Auckland suggest that e-scooterists are exposed to a crash rates 4 to 10 times greater than cyclists (Bodansky et al., 2022; Færdselsstyrelsens, 2020; Fearnley et al., 2020; Mcguinness et al., 2021). These findings have influenced public opinion, even resulting in bans and strict policies for e-scooters in several municipalities worldwide (Guy, 2024; Mao, 2024; Reid, 2023). However, so far, studies comparing bicycle and e-scooter crash rates have *not* accounted for geographical disparities and differences in usage patterns (particularly when comparing privately owned bicycles to shared e-scooters), and these simplifications may skew the crash risk towards e-scooterists. Further, previous studies have indirectly estimated exposure, often utilizing a sample that differed from the one used for the crash counts.

The aim of this study was to leverage technology to compare injury rates between e-scooterists and e-cyclists while controlling for location using high-resolution exposure as a denominator and including only electrically propelled rental vehicles.

2. Methods

Crash and exposure data were collected from seven European cities: Gävle in Sweden; Berlin, and Düsseldorf in Germany; and Cambridge, Liverpool, Kettering, and Northampton in the United Kingdom. Data

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collection took place between July 2022 and August 2023. To control (at least in part) for usage type, we only considered data from rental e-bicycles and e-scooters from the same micromobility-sharing company. Geofencing guaranteed that all rental vehicles were constrained to the same geographical area. In other words, a real-time algorithm onboard the vehicle disabled the electrical propulsion system once the vehicle exceeded the pre-defined boundary. High-resolution GPS data (1–10 Hz) collected from all vehicles in the operator's fleet, were used to compute measures of exposure, and crash data were self-reported by the users. Crashes where riders reported hardware failures as the main cause of the crash were excluded from the analysis. Further, only severe crashes (i.e., those with injuries) were considered in the analysis. In this context, crash rates specifically indicate the rates of crashes resulting in injuries (i.e. injury rate).

Crash rates were computed by dividing the number of crashes by the number, duration, and distance of the trips (three different measures of exposure from GPS). Each crash rate provides a different perspective: crashes per hundred thousand trips addresses the frequency of usage, crashes per thousand hours of travel accounts for variations in the duration of the trips, and crashes per 10 thousand kilometers reflects the risk relative to the distance traveled. In addition to the crash rates, we computed the incidence-rate ratio (an indicator commonly used in epidemiology; e.g., Grobbee et al., 1990) for each of the three measures of exposure. Incidence-rate ratio is the crash rate of e-scooterists divided by the crash rate of e-cyclists. To ascertain the statistical significance of the findings, we calculated the 95% confidence intervals and p-values (Lash et al., 2021). The statistical significance level was set to $\alpha = 0.05$. We developed a mixed-effects model to analyze the crash rates across all cities. This modeling approach prevented cities with more datapoints from disproportionately influencing the results. Within the modeling framework, the cities were treated as a random effect, and the crash rate (on a logarithmic scale) served as the response variable.

3. Results

A total of 686 e-scooterist and 35 e-cyclist crashes with injuries were analyzed. The number of crashes and the crash rates for each city and rider group are shown in Table 1. Except for Berlin and Düsseldorf, crashes involving riders of both vehicle types were reported in all the cities. While there were more e-scooterist crashes than e-cyclist crashes, when exposure was accounted for, the crash rates for e-cyclists exceeded those of e-scooterists (across all three measures of exposure). For all cities combined, the distance covered per trip by e-cyclists was 1.8 km, in contrast to 1.9 km for e-scooterists (Table 1); furthermore, the duration of trips for e-cyclists was 12 min, exceeding the e-scooterist trips by three minutes (Table 1).

Table 2 presents the incidence-rate ratios for e-scooterists versus e-cyclists along with the corresponding confidence intervals and p-values. (Note that the incidence-rate ratio for Berlin and Düsseldorf could not be calculated due to the absence of reported crashes involving e-cyclists). All other cities showed lower rates of e-scooterist crashes compared to e-cyclist crashes for all three exposure measures. These results were statistically significant for all cities except Northampton (Table 2; in Northampton, the incidence-rate ratios calculated using crashes per 100 k trips and crashes per 10 k hours were not significant). Considering all cities combined, on a per-trip basis, the e-scooterists were five times less likely to be involved in a crash than e-cyclists, and this result was statistically significant (Table 2). Using distance as a measure of exposure resulted in the highest difference in crash rates between e-scooterists and e-cyclists compared to exposure measures such as number of trips or duration (Table 2).

4. Discussion

We had unprecedented access to a large amount of micromobility data from several European cities, which made it possible to control for location, usage, and exposure when comparing e-scootering and e-cycling. The results from this study challenge the current literature, which proposes crash rates to be 4 to 10 times higher for e-scooterists than cyclists. On the contrary, we found no evidence suggesting that e-scooterists experience greater crash risk than e-cyclists. In fact, our results indicate that e-cycling may be more dangerous than e-scootering. Although we could not compute incidence-rate ratios for the two cities in Germany (because no crashes with e-bicycles had been reported), in all the other cities e-scootering appeared to be safer than e-cycling.

Bicycles and e-scooters are both two-wheeled, single-track vehicles that require balancing to be operated; however, their geometry and maneuverability are different (Dozza et al., 2023; Li et al., 2023), which makes them suitable for different uses. While e-scooters are typically used in cities for short trips, bicycles and e-bicycles are often used for longer commutes and may also be found on rural roads. E-scooters and e-bicycles also differ in their performance (Dozza et al., 2023; Li et al., 2023; Terranova et al., 2024), crash and injury patterns (Cicchino et al., 2021; Shah et al., 2021; Stigson et al., 2021), interaction with other road users (Dozza et al., 2016; White et al., 2023), and usage patterns (Kohlrautz & Kuhnimhof, 2024). Finally, whether e-scooters and e-bicycles are privately owned or rented also makes a difference (Haworth et al., 2021; Oostendorp & Hardinghaus, 2023); rental vehicles are often located in city centers, have a sturdier construction than their private alternatives, and are mainly a commodity for the user. Recent studies also show that rental micromobility vehicles may be abused, possibly because the user does not need to pay for the consequences of any

Table 1
Distribution of crashes and corresponding crash rates by city and vehicle type. When no crash was reported, crash rates were not meaningful (reported as '–' in table).

City	Rider group	Distance/Trip (km)	Duration/Trip (min)	Average speed/Trip (km/h)	Crashes	Crash rate per 100 k trips	per 1 k hours	per 10 k km
Berlin	e-scooterist	1.68	7.81	12.9	197	2.81	0.22	0.17
	e-cyclist	1.34	10.27	7.8	0	–	–	–
Cambridge	e-scooterist	2.40	10.82	13.3	135	10.86	0.60	0.45
	e-cyclist	2.01	13.07	9.2	24	22.72	1.04	1.13
Düsseldorf	e-scooterist	1.73	7.82	13.3	48	3.47	0.27	0.20
	e-cyclist	1.22	8.27	8.9	0	–	–	–
Gävle	e-scooterist	1.90	9.02	12.6	10	3.93	0.26	0.21
	e-cyclist	0.94	7.18	7.9	2	42.02	3.51	4.47
Kettering	e-scooterist	2.23	10.52	12.7	6	2.91	0.17	0.13
	e-cyclist	1.98	11.51	10.3	3	17.51	0.91	0.89
Liverpool	e-scooterist	2.17	10.82	12.0	156	7.57	0.42	0.35
	e-cyclist	1.09	13.06	5.0	5	35.23	1.62	3.24
Northampton	e-scooterist	2.48	11.93	12.5	134	8.41	0.42	0.34
	e-cyclist	1.46	14.57	6.0	1	48.31	1.99	3.32
All cities	e-scooterist	1.93	9.08	13.2	686	4.99	0.33	0.26
	e-cyclist	1.80	12.26	8.8	35	21.62	1.06	1.20

Table 2
Incidence rate ratios, confidence intervals and p-values for each city. Values with statistical significance indicated in **bold**.

City	Per 100 k trips Incidence-rate ratio	Confidence interval	p-value	Per 1 k hours Incidence-rate ratio	Confidence interval	p-value	Per 10 k km Incidence-rate ratio	Confidence interval	p-value
Berlin	–	–	–	–	–		–	–	
Cambridge	**0.48**	0.31 – 0.74	P < 0.001	**0.58**	0.37 – 0.89	0.01	**0.40**	0.26 – 0.61	P < 0.001
Düsseldorf	–	–	–		–		–	–	
Gävle	**0.09**	0.02 – 0.43	0.002	**0.07**	0.02 – 0.34	P < 0.001	**0.05**	0.01 – 0.21	P < 0.001
Kettering	**0.17**	0.04 – 0.66	0.01	**0.19**	0.05 – 0.75	0.02	**0.15**	0.04 – 0.58	0.007
Liverpool	**0.21**	0.09 – 0.52	P < 0.001	**0.26**	0.11 – 0.63	0.003	**0.11**	0.04 – 0.26	P < 0.001
Northampton	0.17	0.02 – 1.24	0.08	0.21	0.03 – 1.51	0.12	**0.10**	0.01 – 0.73	0.02
All cities	**0.19**	0.12 – 0.33	P < 0.001	**0.21**	0.11 – 0.40	P < 0.001	**0.12**	0.06 – 0.24	P < 0.001

damage to the vehicle (Pai & Dozza, 2025). Previous studies did not control for location, potentially comparing e-scootering in densely populated urban spaces with cycling on rural roads, did not distinguish between rental and privately owned vehicles, and did not differentiate between conventional bicycles and e-bicycles. In contrast, by choosing only rental electric vehicles, and subjecting all vehicles to the same geofencing restrictions, we limited the bias that could be introduced by a potentially different usage of e-scooters and e-bicycles. However, we do not have evidence that mobility is equivalent between rental e-scooters and rental e-bicycles. This is radically important because a difference in usage among transport modes would raise the question of whether a trip (or an hour, or a km driven) on an e-scooter is equivalent to the same on an e-bicycle. It may be worth noting that this general issue applies to all comparisons across transport modes.

Exposure is critical for evaluating crash risk (Dozza, 2017). This paper is yet another evidence that exposure is a critical variable for a fair comparison of injury outcomes—well beyond micromobility applications (Goodall, 2021). Although, it is well-known that comparisons from injury databases require exposure to be trustworthy (Wolfe, 1982), it is often only roughly estimated (Merlin et al., 2020). Historically, exposure could not be measured either with high resolution, from a large dataset, or from the same population incurring injuries. In this study, we computed three different measures of exposure: number, distance, and duration of the trips, which are common surrogates for exposure in the literature (Goodall, 2021). We used these measures as denominators to calculate injury rates. While all these measures have a high resolution in space and time (because they come from GPS collected several times per second), they led to different values for the incidence-rate ratio (Table 2). Using distance traveled (i.e., 10,000 km) as a surrogate for exposure resulted in the highest difference in injury rates between e-cyclists and e-scooterists, as indicated by the incidence-rate ratios. Among all cities, the incidence-rate ratios calculated based on the distance traveled were notably lower than those obtained using alternative denominators such as trip count (i.e., 100,000 trips) or time (i.e., 1,000 h). Most importantly, independent of how exposure was computed, all trends were consistent across all cities and suggest that e-scooterists experience lower crash risks than e-cyclists.

Although, our findings suggest that e-scooterists may be safer than e-cyclists in urban environments, we only considered crashes involving injured riders using a shared system in a few European city centers in one year. We also assumed that underreporting—an important and well-documented issue especially for micromobility—affects e-scootering and e-cycling equally. Furthermore, the relatively small number of e-cyclist injuries in some of the studied cities (and the absence of reported e-bicycle injuries in two cities) highlights the limitation of the dataset and introduces a degree of uncertainty into the injury rate comparisons. We did not consider whether post-crash consequences and injuries may be more severe on an e-bicycle (where the rider seats higher and dismounting may be harder) than on an e-scooter. It is important to acknowledge that injury data were self-reported by users. However, in the context of this study, where users had no clear incentive to misrepresent injuries, we believe the potential for misreporting is limited. Finally, we assumed the two customer populations to be equivalent. Therefore, while our study is enough to challenge the current scientific literature portraying e-scootering as riskier than cycling, our study does not provide conclusive evidence that one vehicle is safer than the other.

Leisure trips have been found to increase crash risk (Pai & Dozza, 2025); therefore leisure trips may have biased our analysis if they were not equally distributed between e-scootering and e-cycling. Recent studies suggest that rental e-scooters are more often used for leisure activities than traditional *private* bicycles (Pai & Dozza, 2025; Shah et al., 2023). However, we still do not know whether *rental* e-bicycles are used for leisure as much as rental e-scooters. In our study, where the geographical location was confined to highly urbanized city centers, e-bicycles were found to be used for shorter trips and be slower than e-scooters. While this result may suggest that e-scooters provide better mobility than e-bicycles in city centers, here it is important to highlight that e-cycling was not riskier because it was faster.

Future studies should include data from more cities, possibly also from outside Europe and importantly, strive to collect data on a larger number of e-bicycle trips to improve the statistical power of injury risk comparisons. Underreporting should be prevented or measured (possibly with the use of in-vehicle technology), and the equivalence of the demographic of the e-scooter and e-cyclist populations should be verified. Because crashes with bicycles and e-scooters are not necessarily the same and result in different injuries (Cicchino et al., 2021; Shah et al., 2021), future studies should estimate the extent to which vehicle-type biases injury occurrence and reporting. Finally, future studies should reflect on the mobility equivalence between e-bicycles and e-scooters; considering whether cyclists prefer different routes and whether vehicle type influences specific behavior (such as running red lights). Furthermore, when more nuanced information about behavioral patterns is available, relying solely on exposure data from GPS, as done in this study, may not be enough. That said, with the recent advances and widespread availability of global positioning technology in many vehicles, it is now possible to estimate exposure accurately and from the same population experiencing the injuries. GPS data also include absolute time stamps that can be used to prevent specific time intervals (e.g., time of the day, day of the week) from biasing the safety analyses. Exposure derived from GPS and geofencing should become standard practice for a fair comparison across transportation modes including automated driving (Di Lillo et al., 2024), and for the evaluation of safety interventions, such as advanced driving/riding assistance systems (Abdel-Aty & Ding, 2024).

In conclusion, our findings indicate that e-scootering may not be riskier than cycling, as several studies have advocated in the last few years. When controlling for location, exposure, and usage, our incidence-rate ratios analysis shows that e-scooterists experience lower crash risk than e-cyclists. While our analysis also has some limitations and cannot be considered conclusive evidence, taking location, usage, and high-resolution exposure into account—which our analysis did contrary to previous studies—is paramount for a fair comparison of injury risk among transportation modes.

Declaration of generative AI and AI-assisted technologies in the writing process

During the preparation of this work the authors used Grammarly and Microsoft Copilot to correct grammar and review language. After using these tools, the authors reviewed and edited the content as needed and take full responsibility for the content of the publication.

CRediT authorship contribution statement

Rahul Rajendra Pai: Writing – review & editing, Writing – original draft, Visualization, Validation, Software, Methodology, Investigation, Formal analysis, Data curation. **Marco Dozza:** Writing – review & editing, Writing – original draft, Validation, Supervision, Project administration, Methodology, Investigation, Funding acquisition, Formal analysis, Conceptualization.

Declaration of competing interest

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests: Swedish Transport Administration funded the research. The authors have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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