A retrospective registry analysis of the transport-related health burden of wheeled recreational devices in Queensland, Australia

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Abstract

Objective: Evaluate injury patterns from wheeled recreational devices (WRD) in the public space and explore risk factors for hospital admission.

Method: A cross-sectional analysis of WRD injury prevalence and risk factors for hospital admissions was conducted using data from the Queensland Injury Surveillance Unit (QISU) database for 2007 to 2017. Descriptive statistics and a log-binomial regression model were used to calculate adjusted relative risk for hospital admission.

Results: Most WRD injury in the public space was related to stand-alone WRD injury events such as falls, with few reported WRD users being hit by vehicles from 2007 to 2017. Stand-alone WRD injury events had a higher independent risk of hospital admissions when injured in the head/neck/face (RR 2.08, 95%CI 1.6 to 2.8, p<0.001), and when the injury was a fracture (RR 2.57, 95%CI 2.1 to 3.3, p<0.001) or a brain injury (RR 3.19, 95%CI 2.5 to 4.1, p<0.001).

Conclusion: Head, brain and facial injuries and fractures are leading preventable factors for hospital admissions due to WRD injury. These types of injuries generate a preventable burden to the health system.

Implications for public health: The results support the need to consider legislation regarding mandatory helmet use for non-motorised WRD when used on public roads and footpaths, while further research is conducted. This strategy could reduce the long-term health outcomes associated with head, face and brain injury in young commuters.

Key words: trauma, longboards, kick-scooter, brain, neurological, prevention

Pedestrian falls are a source of injury among all age groups.[1,2] Despite the injury potential and associated societal costs,[3] little research has specifically addressed stand-alone pedestrian events given that they are traditionally not considered a traffic casualty.[3,4] Not surprisingly, there is even less research on a specific category of pedestrian activity, the use of wheeled recreational devices (WRD). Therefore, the present paper sought to address this gap in the literature by analysing a trauma registry from Queensland, Australia, to explore injury health outcomes associated with the use of WRD on public roads and footpaths. In Queensland, the legal definition of a pedestrian includes the use of WRD such as rollerblades, roller skates, foot scooters, (including those with a small electronic motor with a top speed of 20km/h) and skateboards.[5] WRD is a distinct category that excludes wheeled toys used by children under 12 such as pedal cars. It also excludes personal mobility devices (rideable) such as powered scooters with a top speed of 25km/h.

People aged under 18 years have been usually reported as overrepresented in WRD injury in the recent literature.[6,7] However, injury due to WRD is not restricted to this age group, with adults also being frequently injured.[8,9] Moreover, the number of adults injured while riding push scooters in Bern, Switzerland, has been reported to have risen from 2007 to 2017.[10] Some academic attention has been devoted to general WRD injury potential, including severe injury[11-15] and fatality.[11,14,16] The use of WRD for transport is popular among younger people in the U.S.[12,17] An exploratory survey of skateboard use in the US and Canada found that 85% of skateboard use is for transport.[18] Despite the health benefits associated with active travel, there are associated injury risks. It is important to consider that WRD travel can occur on both public footpaths and roads; in the present document we refer to this physical area as the public space. The use of skateboards for travel differs from use in designated areas such as skate parks in that users are focused on performing tricks in the latter. The proportion of WRD trauma that occurs in the public space has been reported in the literature in the range of 29% to 74%,[11,19-21] with 39% reported in Queensland, Australia.[12] Such injuries are associated with worse health outcomes than those occurring in designated areas for WRD use.[22,23] In the US from 2000 to 2017 there was a population unadjusted 50% increase in skateboard injuries occurring on a street or highway and a 100% increase in those occurring on other

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public property despite declining around 50% in home/school areas and around 1% in designated areas.[6] This increase in skateboard injury occurring in the public space was reported in the US despite a total decline of skateboard users from 10 million in 2006 to 6 million in 2017.[6]

These findings together highlight the increasing importance of WRD use in the public space. Nevertheless, to the best of our knowledge, only one previous study has been devoted specifically to address WRD injury patterns in the public space.[11] Most of the other studies reporting WRD injuries in the public space report skateboards and scooters as the WRDs most frequently involved.[19-21] Although these studies report the occurrence of WRD injuries in locations such as public streets and footpaths, they do not specifically look at the injury patterns and injury mechanisms occurring in those areas and instead report injury patterns from all locations. For example, Keays and Dumas (2014) presented injury patterns from longboards (skateboards specially design for cruising) and skateboards and suggested longboard injury occurred mainly on streets and users were more likely to be injured in areas with traffic, but the injury patterns specific to the street use were not reported.[13] Moreover, despite Fang and Handy, (2017) reporting injuries occurring in the street, the injury sample was relatively small (n=557 injury reports), and only focused on skateboards.[11]

In the present paper, we aim to report the patterns of WRD injury in public space across Queensland from 2008 to 2017 and explore risk factors for hospital admission. The epidemiological understanding of such injuries is important to discuss for two reasons. Firstly, in the context of increasing commercially available e-motorised WRD designed for transport,[22,23] the study of injury patterns from un-motorised WRD used in the public space could provide early insights about the types of injuries that are likely to occur to due to the uptake of motorised WRD. Secondly, increasing knowledge regarding the injury patterns of different WRD and exploring risk factors for hospital admissions could help inform prevention strategies needed to reduce the present health-related non-motorised WRD injury and the future motorised WRD injury burden.

Methods

Study setting

The research team retrospectively reviewed the Queensland Injury Surveillance Unit (QISU) database as part of a wider project looking to study pedestrian trauma in Queensland, Australia. Ethics approval was provided by the Royal Brisbane Women Hospital (RBWH) and the Queensland University of Technology (QUT) ethics offices Ref No: LNR/2019/QRBW/54351/(QUT1900000454). QISU is an ongoing collecting dataset from 16 active participating hospitals in Queensland. However, between 2007 and 2017 there were available records from 31 institutions. This data represents approximately one-quarter of the state population. The database contains information regarding age; gender; place where the injury occurred; mechanism of injury; activity while injured, including the use of vehicles such as bicycles or WRD; injury descriptions in text format; body location; diagnostic codes for the type of injury using the International Classification of Diseases (ICD)-10AM codes; ICD-10AM definitions; intent (intentional non-intentional); mode of separation, which refers to the place or the status of a patient at the end of care in a particular health service (QISU data for WRD injury in the public space coded mode of separation from the ED as 1: Admitted [Excl. ED bed], 2: Did not wait in ED, 3: Died in the ED, 4: ED-service event completed - discharged, 5: left after treatment in ED commenced, and 6: Transfer to another hospital), and injury date/time.

Data extraction, inclusion and exclusion criteria

We included data on the following variables: age, gender, mechanism of injury, injury body location, activity while injured, ICD-10AM classifications, injury text descriptions, separation, intent, and place of injury. Data regarding time of injury were excluded due to missing data and ICD-10AM codes given that the information of the diagnosis was already coded by QISU. In the variable 'activity while injured' we excluded any injury that was not related to WRD. Similarly, we excluded any injury that did not occur on public roads and footpaths in the variable place of injury. Because of the potential for code misclassification for pedestrians[24] and falls from skateboards,[9] variables such as mechanism of injury and type of injury contained in ICD-10 AM classifications were manually inspected, re-coded and validated using the injury text descriptions. For the ICD-10AM classifications incorporating diagnosis, the variables were re-categorised into fractures, superficial injuries, sprains and strains, contusions, open wounds, brain injury, dislocations, ruptures of ligaments and other injuries. As a case in point, ICD-10AM definitions coded for different participants indicated 'Fracture of great humerus' or 'Fracture of foot unspecified' or 'Fractures of first rib'. These three cases were recoded to 'Fractures'.

Data analysis

Data collection in registries such as QISU do not inherently lend themselves to an epidemiological study design. Hence, it has been suggested that the type of analysis conducted on the registry data determines the type of study (cohort, cross-sectional, case-control) in the traditional epidemiological sense.[25] In this paper, we conducted a cross-sectional study of the prevalence of different WRD injury characteristics using descriptive statistics such as frequencies and proportions. Then, we evaluated the association between variables using the chi-square test of independence to explore which variables could be included in a multivariate model of the risk factors for hospital admission. Finally, we entered the statistically significant associated variables (alfa=0.05) into a multivariate log-binomial regression model[26-28] to quantify the adjusted relative risk of the factors associated with the dichotomous outcome of separation (hospital admission, emergency department presentation, deaths in the emergency department). For separation, we used hospital admissions as the variable of interest and as an index for quantifying the health burden of WRD injury outcomes.

It has been suggested that health burden estimation is one of the strengths of cross-sectional analysis in health research[29,30] and that log-binomial regression is an appropriate alternative to logistic regression for multivariate models in cross-sectional analyses when the desired statistical outputs are relative risks.[28,31] A log-binomial model is similar to logistic regression; everything is common between the two models with the exception of the link function (using a log link instead of a logit link) and the reporting of the magnitude of association is reported in terms of relative risk (RR) and not odds ratios (OR).[28]

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The term 'relative risk' has been traditionally used to convey the relative probability calculations in both cohort (for incidence ratios) and cross-sectional studies (for prevalence ratios).[32] Both ratios are calculated by using the same underlying mathematical construct – the relative probability of an event or outcome occurring in one group compared with another[33,34] – and it is considered a more accurate measure of association than OR for cross-sectional analyses.[32-35] The preference for RR over OR comes from the fact that when the prevalence of the health outcome is common (usually defined as above 10%), OR substantially overestimate the magnitude of the effect relative to RR estimations.[36,37] In addition, OR estimates are usually interpreted in a way similar to that of RR, which is theoretically and practically misleading.[38] Therefore, we decided to use RR to estimate the magnitude of association for the present study. All the analyses were conducted in IBM SPSS statistics version 25.

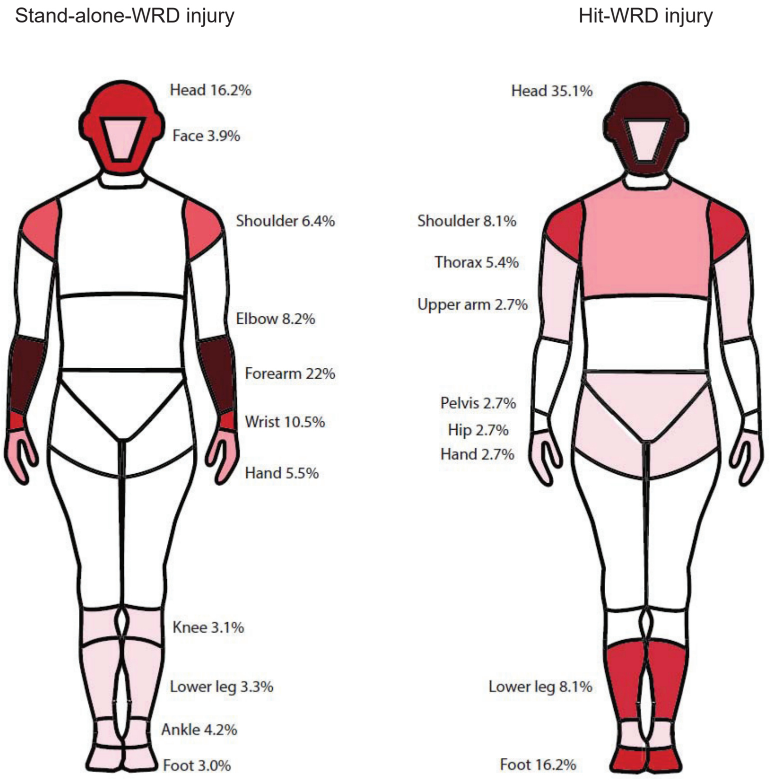
Results

In total, there were 1,967 WRD injuries treated in the QISU emergency departments from 2008 to 2017 occurring in the public space. Of these, 1,930 were events where the user was injured alone (or stand-alone WRD events: 98.1%) such as falls (99.2%) and rolling the ankle/hitting or being cut by objects while using the device/injuring the foot while stopping (0.8%). In the additional 37 injuries, the WRD user was hit by a vehicle (or hit-WRD events: 1.9%) such as cars (94.6%) and bicycles (5.4%) (see Table 1). Moreover, 76% of hit-WRD events required hospital admission in contrast to 20% of stand-alone-WRD injury events. However, the total number of admitted patients was higher for stand-alone-WRD events, 330 compared to 16 (see Table 2). There were no reported deaths in the emergency department from WRD use in the public space within QISU in the analysed period. The age distribution was left-skewed with a median of 12 years and an interquartile range of 10 to 15 years. When considering WRD type, skateboards accounted for 1,154 injuries (58.7%), scooters for 743 (37.8%) and rollerblades and skates for 70 injuries (3.6%). Due to the low number of injuries for rollerblades and skates they were excluded from further analysis. The summary of the general characteristics of skateboard and scooter injuries by injury mechanism can be found in Table 1 and Figure 1.

Table 1: Sample general characteristics of Wheeled Recreational Vehicle (WRD) injury in the traffic environment.

Variables	Stand-alone-WRD injury				Hit-WRD injury			
	Skateboard		Scooter		Skateboard		Scooter	
	n = 1,146	%	n = 714	%	n = 8	%	n = 29	%
Gender								
Male	893	77.9%	498	69.7%	8	100.0%	22	75.9%
Female	253	22.1%	216	30.3%	0	0.0%	7	24.1%
Age								
0–9	106	9.2%	289	40.5%	0	0.0%	14	48.3%
10–14	599	52.3%	370	51.8%	7	87.5%	15	51.7%
15–19	283	24.7%	42	5.9%	0	0.0%	0	0.0%
20+	158	13.8%	13	1.8%	1	12.5%	0	0.0%
Body location								
Head, neck, face	196	17.1%	193	27.0%	3	37.5%	11	37.9%
Trunk	30	2.6%	19	2.7%	1	12.5%	2	6.9%
Upper extremity	646	56.4%	352	49.3%	0	0.0%	5	17.2%
Lower extremity	181	15.8%	104	14.6%	4	50.0%	7	24.1%
Unspecified	16	1.4%	10	1.4%	0	0.0%	1	3.4%
Multiple injuries	77	6.7%	36	5.0%	0	0.0%	3	10.3%
Type of injury								
Fracture	454	39.6%	280	39.2%	1	12.5%	11	37.9%
Superficial injury	182	15.9%	152	21.3%	1	12.5%	8	27.6%
Sprain or strain	274	23.9%	123	17.2%	3	37.5%	6	20.7%
Contusion	45	3.9%	29	4.1%	0	0.0%	0	0.0%
Open wound	76	6.6%	81	11.3%	0	0.0%	3	10.3%
Brain injury	35	3.1%	10	1.4%	1	12.5%	1	3.4%
Dislocation	23	2.0%	7	1.0%	0	0.0%	0	0.0%
Rupture of ligaments	3	0.3%	0	0.0%	0	0.0%	0	0.0%
Other	54	4.7%	32	4.5%	2	25.0%	0	0.0%
Separation								
Hospital admissions	205	17.9%	118	16.5%	3	37.5%	13	44.8%
ED presentations	941	82.1%	596	83.5%	5	62.5%	16	55.2%

Figure 1: Injury patterns by anatomical location in WRD use in the traffic environment.



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Test of association for model inclusion

Gender (χ^2=15.592, p<0.001), age (χ^2=359.629, p<0.001), body location (χ^2=27.303, p<0.001) and type of injury (χ^2=37.745, p<0.001) were statistically significantly associated with WRD type for stand-alone WRD injury. No statistically significant association was found between WRD type and separation for stand-alone WRD injury or for any variable with hit-WRD injury. Table 2 summarises the studied variables in relation to separation as an index for the health burden of stand-alone WRD injury in Queensland. Gender (χ^2=4.145, p<0.042), age (χ^2=9.777, p<0.021), body location (χ^2=89.015, p<0.001) and type of injury (197.184) were statistically significantly associated with separation. No statistically significant association was found between separation and WRD type for stand-alone WRD injury or for any variable with hit-WRD injury. Table 2 shows prevalence differences of at least 10% between admitted and not-admitted patients in head/neck/face and upper extremities for injury by anatomical locations. Moreover, there were prevalence differences of at least 10% in fractures, sprain/strains and brain injury.

Results of the multivariate model

A log-binomial regression model is presented in Table 3 showing the estimated hospital admission adjusted relative risk of pedestrian stand-alone WRD injury based on the statistically significant dependent variables: age (20+ as reference), gender (female as reference), body location (head/neck/face, upper extremities and all other injury locations collapsed as reference category) and type of injury (fractures, sprain/strains, brain injury and all other injury collapsed as reference category). The log-binomial regression model reported higher age and gender-adjusted relative risk of hospital admission for stand-alone WRD injured in the head/neck/face (RR 2.08, 95%CI 1.6 to 2.8, p<0.001) with diagnosis of fractures (RR 2.57, 95%CI 2.1 to 3.3, p<0.001) and brain injury (RR 3.19, 95%CI 2.5 to 4.1, p<0.001). Those WRD users suffering from a stand-alone WRD injury that developed injuries to the upper extremity (RR 0.70, 95%CI 0.5 to 0.9, p=0.003) and sprain and strains (RR 0.3, 95%CI 0.2 to 0.6, p<0.001) were found to be at lower risk of hospital admission compared with treatment in the emergency department. Goodness of fit statistics results from the SPSS output reported a Deviance/df (D/df: 1.09), Person Chi-squared (χ^2=64.65, χ^2/df=1.025) and an omnibus test (Likelihood Ratio χ^2=268.072, p<0.001).

Table 1: Sample general characteristics of Wheeled Recreational Vehicle (WRD) injury in the traffic environment.

Variables	Stand-alone-WRD injury				Hit-WRD injury			
	Admission		Emergency Department		Admission		Emergency Department	
	n = 330	%	n = 1,600	%	n = 16	%	n = 21	%
Gender								
Male	256	79.3%	1135	73.8%	12	75.0%	18	85.7%
Female	67	20.7%	402	26.2%	4	25.0%	3	14.3%
Age								
0–9	62	19%	333	22%	9	56%	5	24%
10–14	191	59%	778	51%	6	38%	16	76%
15–19	51	16%	274	18%	0	0%	0	0%
20+	19	6%	152	10%	1	6%	0	0%
Body location								
Head, neck, face	127	39%	262	17%	11	69%	3	14%
Trunk	12	4%	37	2%	0	0%	3	14%
Upper extremity	135	42%	863	56%	0	0%	5	24%
Lower extremity	40	12%	245	16%	4	25%	7	33%
Unspecified	2	1%	24	2%	0	0%	1	5%
Multiple injuries	7	2%	106	7%	1	6%	2	10%
Type of injury								
Fracture	167	52%	567	37%	8	50%	4	19%
Superficial injury	56	17%	278	18%	2	13%	7	33%
Sprain or strain	12	4%	385	25%	2	13%	7	33%
Contusion	4	1%	70	5%	0	0%	0	0%
Open wound	23	7%	134	9%	1	6%	2	10%
Brain injury	35	11%	10	1%	2	13%	0	0%
Dislocation	7	2%	23	1%	0	0%	0	0%
Rupture of ligaments	0	0%	3	0%	0	0%	0	0%
Other	19	6%	67	4%	1	6%	1	5%
WRD type								
Skateboard	205	63%	941	61%	3	19%	5	24%
Scooter	118	37%	596	39%	13	81%	16	76%

Discussion

Summary of most relevant results

The majority of WRD injuries in the public space were stand-alone WRD injury events (98%) such as falls with few hit-WRD injury events (2%). Despite hit-WRD events resulting in a higher proportion of patients being admitted to hospital, the total number of admitted patients was considerably higher from stand-alone WRD events than hit-WRD events. Fractures, brain injury and injuries of the head, neck and face were found to be independent risk factors for hospital admission in stand-alone WRD events.

Discussion of relevant results

The finding that adolescent male pedestrians are more frequently involved in WRD injury is consistent with previous reports[8,11,14,15,19,20,23,39-42] including research in Australia.[15,39,43] This is of little surprise as the literature reports a well-known gender gap in WRD users with the majority of them being male.[17] Similar to Lindsay and Brussoni (2014), falls were the most common mechanism of injury from skateboards and scooters.[40] However, to the best of our knowledge, we seem to be the first to report that: i) falls are the most common mechanism of injury for WRD occurring in the public space; and ii) the total number of hospital admissions from injuries related to WRD use in the public space is more frequent for stand-alone WRD events relative to hit-WRD events.

There was a higher overall hospital admission rate (17%) for pedestrian WRD in the public space in Queensland from 2008 to 2017 when contrasted with 5.3% admission of all WRD injury in Brisbane 2004 to 2013[20] and 15% in Queensland from 1999 to 2007.[15] Additionally, this estimate is also higher when considering 3–5% admission rate from all WRD injury in the US,[19,21] 6% in Canada[13] and 10.2% in Victoria, Australia.[44] However, Chapman et al. (2001) reported similar admission rates (16%) for children suffering trauma from scooters

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Table 3: Log-binomial model of predictors for hospital admission due to Stand-alone-WRD events injury.

Parameter	B	Std. Error	95%CI Lower	95%CI Upper	Hypothesis Test Wald Chi-Square	Hypothesis Test df	Hypothesis Test p value	Relative Risk	95%CI Lower	95%CI Upper
(Intercept)	-2.480	0.2515	-2.973	-1.987	97.271	1	<0.001	0.084	0.051	0.137
Age										
0-9	0.084	0.2307	-0.368	0.536	0.134	1	0.715	1.088	0.692	1.710
10-14	0.368	0.2092	-0.042	0.778	3.093	1	0.079	1.445	0.959	2.177
15-19	0.224	0.2292	-0.225	0.673	0.953	1	0.329	1.251	0.798	1.960
20+ (Reference)	0							1		
Gender										
Male	0.081	0.1214	-0.156	0.319	0.450	1	0.502	1.085	0.855	1.376
Female (Reference)	0							1		
Injury location										
Head, neck, face	0.732	0.1445	0.449	1.015	25.694	1	<0.001	2.080	1.567	2.760
Upper extremity	-0.430	0.1435	-0.712	-0.149	8.998	1	0.003	0.650	0.491	0.861
Other Locations (Reference)	0							1		
Type of injury										
Fracture	0.943	0.1246	0.698	1.187	57.213	1	<0.001	2.567	2.011	3.278
Sprain or strain	-1.112	0.3071	-1.713	-0.510	13.104	1	<0.001	0.329	0.180	0.601
Brain injury	1.163	0.1207	0.926	1.399	92.756	1	<0.001	3.199	2.525	4.053
Other type of injury (Reference)	0							1		

in Sydney.[39] The higher rates of admission for the present sample could be explained by the fact that this study was focused on WRD occurring on public roads and footpaths (including WRD hit events), while the majority of previous research has reported WRD admissions irrespective of the place where the injury occurred. Moreover, skateboard use outside designated areas has been associated with higher injury severity[14] and longboard use has been associated with a higher frequency of severe injury[13] including neurological trauma when compared with skateboards.[41] This is particularly concerning in the context of increased commercially available innovative and electrically powered WRD[45] designed for commuting or longer riding times that could increase risk exposure and trauma energy transfer.[22] This is notably applicable to Queensland given the prevalent use of such devices by working-age adults in Brisbane.[46,47] Hence, it is important to develop a research agenda that monitors severe injuries requiring hospital admission from motorised and non-motorised WRD in Queensland to inform effective prevention strategies.

In our data, fractures were the most common injury suffered by WRD; this is congruent with previous reported WRD injury research in Europe,[10,48] the US,[19,21,49] Canada[40] and Australia[15,20,39] reporting fractures as the most frequent injury from WRD use in any location. Furthermore, in the US it has being reported that approximately one in seven fractures presenting to a level I trauma hospital were related to WRD.[50] This is of considerable importance in light of a meta-analysis showing an association between fractures and subsequent low bone mass in children.[51] One of the included studies in this meta-analysis[52] reported lower bone mass after four years in children with a previous fracture compared with children without a previous fracture after repeated bone density measures.[51] More recently, Farr et al. (2014) reported evidence supporting that children and adolescents with distal forearm fractures (DFF) with mild trauma have secondary compromised bone strength at the distal radius.[53] Therefore, interventions aimed at preventing fractures from WRD falls in the public space could not only prevent fractures but have a potential impact in maintaining a healthy bone mass and strength in the paediatric population.

The analysis showed that different WRD used as a pedestrian can result in different injury patterns by anatomical location and type of injury. The stand-alone WRD injury events from skateboarders had a higher frequency of sprains and strains than with scooters. This is consistent with Bandzar et al. (2018) who reported that skateboarders had a higher frequency of sprains and strains when compared with hoverboards in the US.[19] Furthermore, the analysis showed that scooter riders have a higher frequency of superficial injuries, as has been previously reported by Lindsay and Brussoni (2014).[40]

Despite previous results showing that scooters tend to be associated with a higher frequency of superficial wounds to the face,[54] the present study found a higher frequency of open wounds with scooter use, with 66% of all scooter open wounds occurring on the head, face or neck. This finding is of importance given the potential for severe bleeding due to a high blood supply to the face,[55] risk of short-term complications such as infections and long-term psychological consequences due to the social stigma attached to facial disfiguration.[55-57]

Findings from this investigation suggest that the health burden of stand-alone WRD pedestrian injury, especially for skateboards and scooters, is associated with a considerably higher risk of hospital admission secondary to injuries in the head (from superficial injuries through open wounds, concussions to brain haemorrhage). This is congruent with the literature suggesting that WRD head trauma accounts for 10% of patients attending emergency departments from all head trauma presentations[58] and explains the growing clinical interest in skateboard use and brain injuries.[9,41,58] Lustenberger et al. (2010) found that riding a skateboard in the street/highway was a predictor of brain injury in the US.[49] Additionally, Tominaga et al. (2015) reported that skateboarders with head trauma have higher injury severity and longer hospital stay than those without and that skateboarders with head trauma had a 50% chance of

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suffering an intracranial haemorrhage.[9] Ma et al. (2018) reported the majority of the head trauma secondary to skateboard injury in 51 patients from two hospitals in Brisbane resulted in minor and moderate injury.[41] However, approximately 30% of patients suffered serious and severe injuries leading to long-term disabilities such as hemiplegia, deafness and facial palsy.[41] In the case of the present study, data from 1,967 WRD injuries in 31 hospitals in Queensland showed that patients with head/face/neck and brain injury had a higher independent (of age and gender) relative risk of hospital admissions. Traumatic brain injury is the leading cause of mortality and disability in children and young adults[59] and it is not only associated with severe short-term health outcomes such as functional and cosmetic deformity,[60] but with long-term outcomes such as intellectual disability,[61] premature mortality, low education and welfare recipiency, even for mild brain injury such as concussions.[62] The above discussion highlights that prevention of WRD head and face injuries could reduce the burden of short, and long-term health outcomes.

Implications for public health

Despite the health burden of WRD injury from its use in the public space, the use of a helmet is not legally required in Queensland when using a non-motorised WRD for transport.[63] The use of a helmet has been shown to reduce mild and severe brain injury and mortality from WRD use.[49,58] Although the body of evidence suggesting benefits of helmet use specifically in the case of WRD seems small, a relative recent systematic review of bicycle helmet use found that helmet use was associated with 51% odds reductions for head injury and 69% odds reduction for severe head injury.[64] Given that travel speeds of non-powered skateboards seem to be equivalent to the lower distribution of cycling travel speeds,[17] the magnitude of reductions of the odds for head injuries in the case of skateboarders could be lower. The legal requirement of helmet use for WRD users could have a positive effect on injury prevention, especially considering that legislation has proven to increase helmet use in other vehicles[64-66] and the fact that helmet use has been associated with lower odds of head injury in the use of skateboards and scooters.[40]

Another aspect of safety that should be considered for prevention when approaching the problem from a safe system perspective is the role road and footpath maintenance and surface design plays in WRD falls incidence and injury severity.[67] As a case in point, consider that Forsman (2001) reported that the most severe injuries from WRD use were caused by the skateboard hitting surface irregularities.[14] This implies that construction and maintenance of footpaths and roads should take into account common commercial WRD wheel size to reduce the likelihood of the wheels becoming heavily jolted, redirected or stopped by surface irregularities. Even surfaces eliminate the possibility of the small wheels of WRD becoming trapped by uneven surfaces,[10,18,43,48] while footpaths designed with impact-absorbing surfaces have the potential to reduce the severity of head injuries.[68] Even footpaths designed with impact-absorbing materials might not only help prevent injuries for WRD users but also reduce the incidence and injury severity of pedestrian falls.[68,3]

Limitations

The results of the present paper should be interpreted with caution. There is variability in the yearly total number of hospitals reporting data to QISU; this might overestimate or underestimate the reported absolute cases for different injury patterns. However, this likely does not considerably bias separation outcomes given that Australian trauma care systems have made a two-decade effort to standardise trauma care based on international standards.[69] Additionally, there are several unavailable variables in the QISU database that might alter the aforementioned analysis. Injury patterns by body location and type of injury might vary by WRD mode of use (cruising, performing tricks, holding onto a motorised vehicle in motion), level of experience, BMI, body composition, subtypes of WRD (e.g. skateboard, longboard) and use of protective gear. For example, it has been suggested in the literature that 33% of skateboard injuries occur in beginner skateboarders.[70] Moreover, injury severity is likely to be affected by behavioural factors including substance abuse[71] and distraction.[72] Furthermore, QISU data does not offer information regarding the length of stay of admitted patients. An additional limitation comes from the specific use of a log-binomial model. Despite the model being increasingly popular among health researchers, the research regarding log-binomial model limitations is emerging,[28] with scant research conducted regarding model evaluation.[73] This implies that there is uncertainty regarding the value of goodness of fit of the model given that the traditional statistics offered in SPSS, such as the Pearson chi-squared, might not be valid for assessing model fit in log-binomial models.[73] Furthermore, new proposed statistical tests such as the Hjort-Hosmer statistic[73] are not available for the SPSS output when running a log-binomial model.

Further research that uses a prospective design is needed, especially when considering the rising heterogeneity of non-motorised and motorised WRD. Furthermore, future research should keep in mind the uncertainty regarding goodness-of-fit tests for log-binomial models and keep up to date with the emergent literature. Finally, it is important to take into account that the sample of hospitals represents approximately one-quarter of the Queensland population and that there is variability in hospital reporting. Therefore, the external validity of the findings is likely limited to the catchment areas covered by the participating hospitals within QISU.

Nevertheless, the present exploratory analysis strongly supports the need for further research regarding injury patterns, mechanism and prevention strategies for the use of WRD (motorised or non-motorised) in the public space.

Conclusion

Pedestrian stand-alone-WRD events are an important contributor to road injuries among the male paediatric population and a preventable health burden. Head trauma is the leading cause of disability in children older than one year.[58] Thus, measures should be taken to reduce the health burden of such events, particularly the risk of superficial injuries and open wounds to the head and brain injuries.

Given the exploratory nature and the retrospective design of the present study, further research needs to clarify the 'true' relationship between WRD injury type, body location and injury severity. Additionally, it is of especial importance to examine the magnitude of the beneficial effects of helmet use in WRD riders for different jurisdictions. In the meantime, it seems an appropriate public health action to reconsider the current

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WRD helmet policy in Queensland when taking into account that the current level of available evidence suggests a reduction of mild and severe brain injury with helmet use.[49,58] This is especially relevant when taking into consideration that crashes between motor vehicles and WRD were not included in the risk factor model for hospital admissions and such events are also associated with traumatic brain injury[41] and deaths.[16] Moreover, recommending the use of full-face helmets for scooter riding could also reduce superficial injuries to the head and open wounds and potentially reduce the short- and long-term health burden from WRD use in the public space. The full-face helmet recommendation could be particularly relevant for motorised scooters, which are very popular for transport in Brisbane,[46,47] Queensland's largest city.

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