

Non-motorised active mobility device use by children in Singapore: Injury patterns and risk factors for severe injury

Aletheia ZH Chia¹*MBBS*, Shu-Ling Chong^{1,2}*MPH*, Sashikumar Ganapathy^{1,2}*MRCPC*

ABSTRACT

Introduction: Wheeled recreational devices (WRDs) include tricycles, bicycles, scooters, inline skates, skateboards, longboards and waveboards, and can cause significant morbidity and mortality. This study aimed to describe the epidemiology and nature of injuries sustained by children from WRD use, and risk factors for severe injury.

Method: We described injuries relating to WRD use in children <18 years who presented to the emergency department of an Asian tertiary hospital between 2016 and 2020. Demographic data, site and nature of the injury, and historical trends were analysed. Risk factors for severe injury (defined as fractures or dislocations), Injury Severity Score ≥ 9 , and injuries resulting in hospitalisation, surgery or death were evaluated.

Results: A total of 5,002 patients with 5,507 WRD-related injuries were attended to over the 5-year study period. Median age was 4.7 years. Injuries related to bicycles (54.6%) and scooters (30.3%) were most frequent, followed by skateboards and waveboards (7.4%), inline skates (4.7%), and tricycles (3.0%). Injuries occurred most frequently in public spaces. Soft tissue injuries (49.3%) and fractures (18.7%) were the most common diagnoses. Upper limb (36.4%) and head and neck (29.0%) regions were the most common sites of injury. Among the patients, 1,910 (38%) had severe injuries with potential morbidity. On multivariate analysis, heavier children of the school-going age who use either scooters, skateboards or inline skates are more prone to severe injuries. Involvement in a vehicular collision was a negative predictor.

Conclusion: WRD use in children can result in severe injuries. Wrist and elbow guards, as well as helmets are recommended, along with adequate parental supervision.

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Keywords: Bicycle, inline skate, paediatric, scooter, skateboard, trauma, tricycle, wheeled recreational device

INTRODUCTION

The Active Mobility Act was introduced in Singapore in 2017 to promote the safe use of personal mobility devices. Non-motorised active mobility devices (AMDs) are popular among children and include tricycles, bicycles, scooters, inline skates, skateboards, longboards and waveboards. While the use of AMDs contributes towards an active lifestyle and gross motor development, such devices can result in injuries. These injuries are commonly mild and self-resolving,¹⁻³ but a small proportion can result in significant morbidity and mortality. About 2 to 20% of scooter-related injuries seen in emergency

departments (EDs) require hospitalisation,^{2,4,5} surgery,^{4,6} intensive care unit (ICU) stay or result in death.^{2,7,8}

There is an increasing trend of injuries related to AMD use. After the modern scooter was popularised in the US in 2000, there was a more than 25-fold increase in ED-treated injuries, with 19 deaths reported between 1999 and 2001.⁸ Injuries vary depending on the type of device used. For example, Keays et al.⁹ found a higher proportion of head and neck injuries in longboarders when compared to lower limb extremities in skateboarders, while Aslam et al.⁶ highlighted the risk of triplanar ankle fractures from scooter use. Injury prevalence and type

¹ Department of Emergency Medicine, KK Women's and Children's Hospital, Singapore

² Duke-NUS Medical School, Singapore

Correspondence: Dr Aletheia ZH Chia, Department of Paediatrics, KK Women's and Children's Hospital, 100 Bukit Timah Road, Singapore 229899.

Email: aletheia.chia@mohh.com.sg

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CLINICAL IMPACT

What is New

- To our knowledge, this is the first Asian study that describes injuries due to the use of recreational devices among children.
- Heavier children of the school-going age who use either scooters, skateboards or inline skates are more prone to severe injuries.

Clinical Implications

- The use of wrist and elbow guards and helmets should be recommended, along with adequate parental supervision.
- Primary prevention should be targeted at school-going children, users of skateboards, inline skates and scooters, and within public spaces such as playgrounds and sports facilities.

is likely to be affected by trends in AMD popularity and use, such as with the introduction of waveboards and motorised devices.

Despite there being many AMDs on the market, studies thus far have focused on 1 or up to 3 specific device types. Understanding epidemiological trends and injury patterns with different AMDs can highlight particular regions and injuries to look out for, and can aid in primary prevention. While helmet use has been shown to reduce the risk of severe injury¹⁰ and concussive symptoms,¹¹ not much is known about other risk factors for severe injuries in children. Identifying predictors for severe injuries can aid in risk stratification, and also inform a multipronged public health approach to reduce severe AMD-related injuries in children.

Our study aims to describe the epidemiology of injuries sustained by children from the use of non-motorised AMDs, who presented to the ED of a large Asian tertiary paediatric hospital. We also aimed to evaluate risk factors for severe injury, as defined by fractures or dislocations, Injury Severity Score (ISS) ≥ 15 , injuries requiring hospitalisation, surgery, or resulting in death.

METHOD

Study design

We performed a retrospective chart review of children who presented with injuries to the ED of KK Women's and Children's Hospital (KKH) in Singapore between January 2016 and December 2020.

KKH is one of 2 tertiary paediatric hospitals in Singapore. From 2016 to 2020, it had an annual attendance of 93,991–16,7269, with 16–22% of patients presenting with injuries. Trauma is managed by a multidisciplinary team consisting of emergency physicians, surgeons, anaesthetists and intensivists.

The data were obtained from the hospital's trauma surveillance registry. Data including circumstances of the injury and International Classification of Diseases-coded diagnoses are prospectively entered by the attending emergency physician into a structured data collection form during the patient encounter. If present, more than 1 injury may be coded for each patient. Data from the visit and subsequent outcomes are collated and verified by a trauma coordinator. Injury text descriptions were manually inspected to validate the corresponding mechanism and type of injury, and to ensure inclusion and exclusion criteria were met. The database is accredited by the Association for the Advancement of Automotive Medicine.

This study was given ethics approval by the SingHealth institutional review board (IRB number 2021/2401).

Inclusion and exclusion criteria

The study included patients below 18 years old who presented to the ED with an injury related to the use of a non-motorised AMD. Patients who were passive bystanders hit by AMDs were not included. Devices considered were tricycles, bicycles, scooters, inline skates, skateboards, longboards and waveboards. Electronic devices such as motorised bicycles, electronic scooters and hoverboards were excluded.

Variables and outcome measures

We reviewed demographic data and circumstances of the injury, including the mechanism of injury, place of injury, mode of transport to the ED and type of device involved. A vehicular collision was defined as there being a collision between the device user and a vehicle, with AMD users either colliding with or hit by a vehicle. This included incidents in carparks or with stationary vehicles. Injuries sustained by passive bystanders who were hit by AMDs were not included.

Injury types were classified into 6 broad categories: soft tissue injuries (e.g. lacerations and contusions), fractures, dislocations, crush injuries, specific organ injuries (e.g. neurological, ophthalmological and abdominal) and others/not specified. The site of injury was recorded and further classified into 6 regions: head and neck, upper limb, lower limb, trunk, groin and buttocks, or not specified. The disposition of the patient and subsequent length of stay in hospital were reviewed, along with the need for surgery.

Severe injury was defined as fractures or dislocations, Injury Severity Score (ISS) ≥ 15 , injuries requiring hospitalisation, surgery, or resulting in death.

Statistical analysis

Categorical variables were reported as frequency with percentages, and analysed with chi-square tests. Continuous variables were reported as the median and interquartile range (IQR), and analysed with Wilcoxon rank sum tests. Univariate logistic analysis was performed for severe injury as defined above. Statistically significant variables were entered into a multivariate logistic regression model. Unadjusted and adjusted odds ratios (aOR), together with their 95% confidence intervals (CIs), were presented.

Statistical significance was taken at P value <0.05 . Statistical analysis was conducted using R version 4.2.0.

RESULTS

A total of 4,972 patients with non-motorised AMD-related injuries were attended to over the study period, with a total of 5,475 injuries. Two patients were excluded due to age and incomplete data. The median age was 7.8 years (interquartile range [IQR] 4.8–11.6). Injuries related to bicycles (54.6%) and scooters (30.3%) were the most common, with a smaller proportion related to skateboards and waveboards (7.4%), inline skates (4.7%) and tricycles (3.0%) (Table 1). There were no injuries related to longboard use. Tricycle users were younger with a median age of 3.4 years (IQR 2.2–5.3), followed by scooters (6.2, IQR 4.3–8.9), bicycles (8.7, IQR 4.9–12.5), inline skates (10.3, IQR 8.3–12.3) and skateboard users (11.3, IQR 8.9–13.2) (Fig. 1).

The most commonly identified place of injury was public spaces, including playgrounds and sports facilities, followed by homes, roads, and school or childcare facilities (Table 1). Eighty (1.6%) injuries occurred as a result of a vehicular collision, with the remaining due to falls or other incidents.

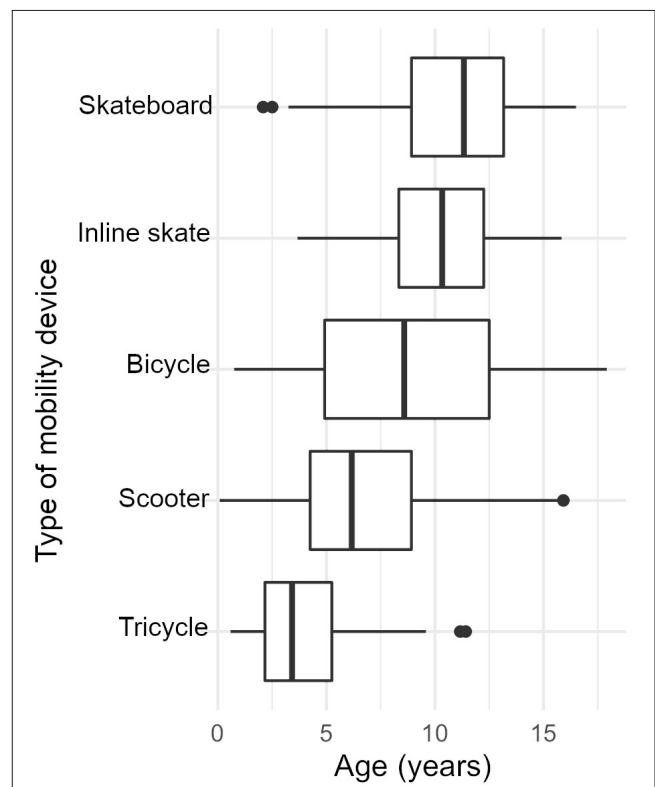


Fig. 1. Age distribution of non-motorised active mobility device-related injuries.

There was a reduction in bicycle- and skateboard-related injuries from 2018–2019, followed by a return to former levels in 2020. The incidence of scooter-related injuries decreased between 2017 and 2020 (Fig. 2).

Of the 5,507 injuries, 2,704 (49.4%) were soft-tissue injuries, 1,995 (36.4%) fractures, dislocations or crush injuries, and 504 (9.2%) organ-involving injuries (including neurological, abdominal, dental and eye injuries) (Table 2). Upper limb injuries were the most common (36.5%), followed by head and neck injuries (29.1%), lower limb (20.4%), trunk (2.8%), and groin or buttock injuries (0.8%) (Fig. 3). The 2 most common specific injuries identified for each device were facial laceration injuries ($n=30$, 19.8%) followed by head injuries with tricycles (28, 18.4%). These were followed by facial lacerations (327, 20.3%); head injuries with scooters (170, 10.6%); facial lacerations (280, 9.1%); head injuries with bicycles (230, 7.5%); fractures of radius and ulna (71, 18.6%); head injuries with skateboards (28, 7.2%); fractures of radius and ulna (53, 22.6%); and supracondylar humerus fractures with inline skates (20, 8.5%).

Twenty-one (0.42%) patients required admission. The Median length of hospital stay was 2.8 days

Table 1. Demographic data and injury circumstances of patients with wheeled recreational device-related injuries

	Overall	Stratified by severity		<i>P</i> value
		Non-severe	Severe	
	n=4972	n=3074	n=1898	
Median age (IQR), years	7.8 (4.8–11.6)	5.5 (4.2–10.8)	9.6 (6.2–12.4)	<0.001
Male sex, no. (%)	3410 (68.6)	2098 (68.2)	1312 (69.1)	0.539
Median weight (IQR), kg	25.9 (17.4–43.0)	22.0 (16.2–37.2)	33.0 (21.4–48.0)	<0.001
Ethnicity, no. (%)				<0.001
Chinese	2299 (46.2)	1451 (47.2)	848 (44.7)	
Malay	1013 (20.4)	598 (19.5)	415 (21.9)	
Indian	948 (19.1)	539 (17.5)	409 (21.5)	
Others	712 (14.3)	486 (15.8)	226 (11.9)	
Year of injury, no. (%)				0.285
2016	1065 (21.4)	651 (21.2)	414 (21.8)	
2017	1113 (22.4)	698 (22.7)	415 (21.9)	
2018	956 (19.2)	578 (18.8)	378 (19.9)	
2019	833 (16.8)	539 (17.5)	294 (15.5)	
2020	1005 (20.2)	608 (19.8)	397 (20.9)	
Mechanism of injury				
Vehicular collision, no. (%)	80 (1.6)	68 (2.2)	12 (0.6)	<0.001
Place of injury, no. (%)				<0.001
Public places, including playgrounds, sports facilities	1619 (32.6)	878 (28.6)	741 (39.0)	
Home	794 (16.0)	583 (19.0)	211 (11.1)	
Road	330 (6.6)	244 (7.9)	86 (4.5)	
School/childcare centre	110 (2.2)	58 (1.9)	52 (2.7)	
Others	2117 (42.6)	1309 (42.6)	808 (42.6)	
Mode of arrival, no. (%)				0.054
Own transport	4377 (88.7)	2702 (88.3)	1675 (89.2)	
Emergency ambulance	519 (10.5)	338 (11.0)	181 (9.6)	
Others	40 (0.8)	19 (0.6)	21 (1.1)	
Type of device, no. (%)				<0.001
Bicycle	2717 (54.6)	1773 (57.7)	944 (49.7)	
Scooter	1506 (30.3)	962 (31.3)	544 (28.7)	
Skateboard, waveboard	368 (7.4)	161 (5.2)	207 (10.9)	
Inline skate	232 (4.7)	71 (2.3)	161 (8.5)	
Tricycle	149 (3.0)	107 (3.5)	42 (2.2)	

IQR: interquartile range

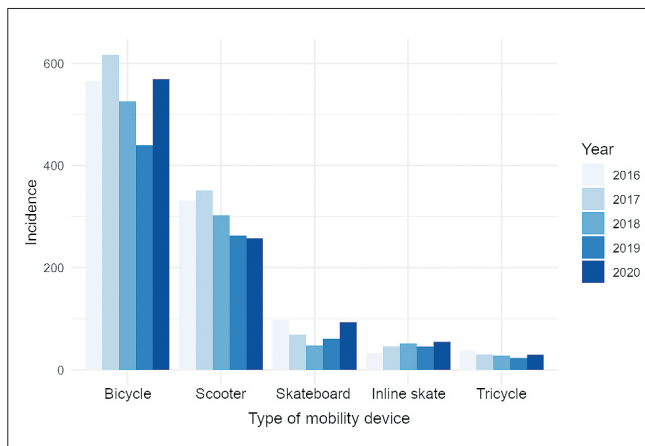


Fig. 2. Incidence of non-motorised active mobility device-related injuries from 2016–2020.

Table 2. Incidence and type of wheeled recreational device-related injuries

Type of injury	Frequency	Percentage
Total	5475	
Soft tissue injury		
Laceration	936	17.1
Contusion	630	11.51
Wound	254	4.64
Sprain, strain	214	3.91
Abrasion	151	2.76
Burn	6	0.11
Other soft tissue injury, not specified	513	9.37
Fracture		
Dislocation	37	0.68
Crush injury	57	1.04
Specific organ injuries		
Neurological injury	429	7.84
Dental injury	37	0.68
Abdominal injury	22	0.4
Eye injury	16	0.29
Not specified	310	5.66
Others	2	0.04

(IQR 1.9–4.8). Six patients (0.12%) required high-dependency care, ranging from 0.6–2.0 days, and 3 (0.06%) patients required intensive care unit (ICU) care, ranging from 0.6–1.6 days. Twenty-eight (0.56%) patients required surgery. There were no mortalities.

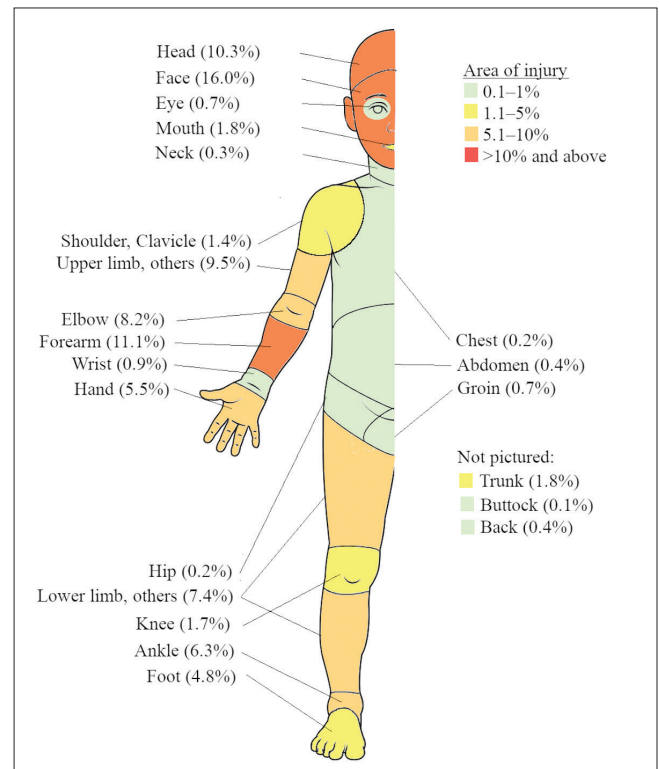


Fig. 3. Site of non-motorised active mobility device-related injuries.

The 3 patients who required ICU care had intraabdominal trauma following a fall from a bicycle, intracranial haemorrhage in a cyclist involved in a vehicular collision, and major head injury from an unwitnessed cycling incident.

Severe injuries were sustained in 1,898 (38.2%) patients. On multivariate analysis (Table 3), patients of school-going age ≥ 7 years (aOR=1.49, 95% CI 1.25–1.77), heavier weight ≥ 30 kg (aOR 1.83, 95% CI 1.55–2.18), Indian (aOR 1.30, 95% CI 1.10–1.53) or Malay ethnicity (aOR 1.19, 95% CI 1.01–1.39), occurrence in a public (aOR 1.86, 95% CI 1.53–2.26) or unspecified place (aOR 1.41, 95% CI 1.16–1.71), along with scooter (aOR 1.29, 95% CI 1.12–1.49), skateboard (aOR 1.86, 95% CI 1.48–2.35) and inline skate use (aOR 3.37, 95% CI 2.48–4.61) were associated with an increased risk of severe injury. Being involved in a vehicular collision was a negative predictor for severe injury (aOR 0.36, 95% CI 0.18–0.65).

DISCUSSION

In this study, we described the epidemiology of AMD-related injuries in children presenting to the ED of a large tertiary paediatric hospital in Singapore, from injury circumstances to diagnosis at ED, and subsequent disposition and outcome. Soft tissue injuries and fractures

Table 3. Univariate and multivariate analysis for severe injury

	Unadjusted analysis		Adjusted analysis	
	OR (95% CI)	P value	Adjusted OR (95% CI)	
School-going age (≥ 7 years)	2.53 (2.25–2.86)	<0.001	1.49 (1.25–1.77)	<0.001
Male sex	1.04 (0.92–1.18)	0.518		
Weight ≥ 30 kg	2.54 (2.26–2.86)	<0.001	1.83 (1.55–2.18)	<0.001
Ethnicity				
Chinese	Ref		Ref	
Malay	1.19 (1.02–1.38)	0.026	1.19 (1.01–1.39)	0.035
Indian	1.30 (1.11–1.51)	0.001	1.30 (1.10–1.53)	0.002
Others	0.79 (0.66–0.95)	0.012	0.83 (0.69–1.01)	0.058
Mechanism of injury				
Vehicular collision	0.28 (0.14–0.50)	<0.001	0.36 (0.18–0.66)	0.002
Place of injury				
Home	Ref		Ref	
Public places	2.33 (1.94–2.81)	<0.001	1.86 (1.53–2.26)	<0.001
Road	0.97 (0.73–1.30)	0.859	0.86 (0.63–1.18)	0.362
School/childcare centres	2.48 (1.65–3.72)	<0.001	1.21 (0.77–1.91)	0.403
Others	1.70 (1.43–2.05)	<0.001	1.41 (1.16–1.71)	0.001
Mode of arrival				
Emergency ambulance	0.86 (0.71–1.04)	0.132		
Type of device				
Bicycle	Ref		Ref	
Scooter	1.06 (0.93–1.21)	0.369	1.29 (1.12–1.49)	<0.001
Skateboard, waveboard	2.41 (1.94–3.01)	<0.001	1.86 (1.48–2.35)	<0.001
Inline skate	4.26 (3.20–5.72)	<0.001	3.37 (2.48–4.61)	<0.001
Tricycle	0.74 (0.51–1.05)	0.102	1.32 (0.89–1.92)	0.163

CI: confidence interval; OR: odds ratio

were the most common diagnoses, while the head and neck, and upper limb were the most common sites of injury. A significant proportion of patients had severe injuries with potential morbidity. Risk factors for severe injury included increased age and weight, Indian or Malay ethnicity, location of the injury, as well as scooter, skateboard and inline skate use. Conversely, involvement in a vehicular collision was a negative predictor.

The age distribution of patients presenting with non-motorised AMD-related injuries is in keeping with the typical age groups that use each device and previous studies,² with tricycle-related injuries more common in younger age groups, and skateboard and inline

skate-related injuries more common in older children. Bicycle- and scooter-related injuries spanned a larger age distribution, pointing towards the versatility and popularity of such devices across ages. Outliers of infants and toddlers with bicycle- and skateboard-related injuries included incidents where patients sat on, pulled, or placed fingers into such devices, highlighting the importance of proper storage and securing of AMDs at home and in recreational facilities.

School-going children were at higher risk of severe injuries. Montagna et al. had also noted a higher risk of fractures in children ≥ 8 years old, although younger children were at higher risk of head and facial injuries.⁵

Older children tend to be larger in size, faster and stronger—features that allow them to go at greater speeds with potential for more serious injury. Teenagers are also more likely to participate in risk-taking behaviour and competitive situations.¹² Education on primary prevention strategies is likely to have higher impact when targeted at school-going age children and their parents. In line with encouraging active play and a shift towards active mobility, schools should play a bigger role in educating parents and children on the risk of such device-related injuries and preventative measures. While traffic safety programmes have been implemented in primary schools since the 1990s,¹³ these typically focus on pedestrian safety and could be further expanded.

When compared to bicycles, inline skates, skateboards or waveboards, scooters were independent predictors for severe injury. Previous studies have also found inline skates to have a higher incidence of fractures than skateboards or scooters.¹⁴ These devices tend to be lightweight with low friction wheels, allowing users to obtain high speeds with little effort.

Our findings also highlight particular injury patterns common in each device type, such as head and face injuries with tricycles, scooters and bicycles, and upper limb fractures with skateboards and inline skates. While our data did not specify particular fracture patterns, previous studies have highlighted the risk of distal radial fractures with skateboarding, inline skating and scooting,¹⁵ and in particular Smith-type fractures with volar angulation.¹⁴

The most common injury type was soft tissue injuries, in keeping with previous studies.^{2,5} However, a significant proportion (38%) of patients did have severe injuries. This consists of patients with fractures or dislocations, an ISS score of ≥ 15 , and requiring surgery or admission, hence indicating a requirement for medical intervention and potential morbidity. There was a low admission rate of 0.42%, compared to other studies with admission rates of 2–20% for scooter injuries^{2,4,5} and 2.4% with tricycles.³ There is a risk of significant injuries with potential long-term morbidity and mortality, with several patients suffering intraabdominal or intracranial injury requiring intensive care. Fractures or dislocations can also have both short-term effects such as reduced mobility with limitations in performing day-to-day activities and schooling, and potential long-term effects including a risk of subsequent low bone density.¹⁶ While such fractures are often successfully managed conservatively in the paediatric population, these can have significant sequelae on children and their families.

Involvement in a vehicular collision was found to be a negative predictive factor for severe injuries. Data from

the US had previously highlighted deaths with collisions between motor vehicles and skateboard/scooter riders.¹⁷ This may be related to the nature of collisions in our cohort, with the majority being low-velocity incidents occurring in car parks, zebra crossings or traffic lights; or of patients crashing into a stationary vehicle. This can be attributed to higher traffic safety awareness in children and parents in Singapore. Traffic safety programmes have been implemented nationwide in primary schools since the 1990s¹³ and continue to be updated. Awareness of potential road-related injuries with boundary setting or close supervision by parents are likely to contribute to a reduction in severe injuries. Parents and children may potentially be more aware of the risk of traffic-related injuries when compared to play at home, in recreational parks, or in schools.

Injuries most commonly involved the upper limb or head and neck regions, and specifically the head, face and forearm (Fig. 2). This suggests key areas of protection with the use of helmets and wrist and elbow guards with such mobility devices. Non-helmet use has been shown to independently increase the risk of concussive symptoms,¹¹ hospitalisation and major head injury in paediatric AMD incidents,¹⁰ with the main influence on helmet use being parental rules and perceived low levels of danger. The use of wrist guards and elbow pads have been shown to protect against wrist and elbow injuries in adult inline skaters.¹⁸ The American Academy of Pediatrics recommends the use of helmets, knee pads and elbow pads while using scooters, and with the addition of wrist guards while using skateboards.¹⁹ Manufacturers of safety equipment and retailers of AMDs should consider these key areas when designing and promoting safety equipment.

To the best of our knowledge, this is the first Asian study of non-motorised AMD-related injuries in the paediatric population, and the first to analyse a large range of device types. Encompassing a 5-year period at the largest paediatric emergency department in Singapore, it may be representative of national trends related to injuries from AMD use. Data are from a surveillance registry, with injury circumstances detailed at the time of patient encounter in the ED. The larger number of injuries studied also allowed for analysis of risk factors for severe injury.

Over the years, public policy and attitudes have shifted towards promoting active mobility in Singapore.²⁰ In line with a shift to a car-lite nation and encouraging healthy behaviour, the National Cycling Plan²¹ was established as a collaborative governmental effort aimed to make cycling a safe, healthy and convenient transport option for Singaporeans. This included building a

comprehensive islandwide cycling network with both intratown and intertown paths, spanning more than 1,300km by 2030. The Active Mobility Act was passed in Singapore in 2017 to regulate the safe use of personal mobility devices,²² including allowing the use of selective mobility devices such as bicycles, skateboards and electric scooters on public paths subject to a set of rules and codes of conduct. Injuries from AMD use have been increasing in adults,²³ and can be expected to increase in the paediatric population in the future. A proportion of these can be expected to be severe in nature, with considerable public health impact. Apart from regulatory measures to enable safer road-sharing, education on the safe use of such devices from a young age will also be key. This can include the need for age-appropriate use of various devices, adequate supervision, and proper use of protective gear.

Our study should be interpreted in the context of its limitations. Being a single-centre study, our findings may not be applicable in other settings. Our study is not representative of AMD users with minor injuries not requiring care at an ED; Baumgartner et al.²⁴ noted that of the 29% of paediatric scooter riders who had accidents, 21.3% required medical consultation. There may also be variability in coding by the attending emergency physician, with the diagnoses occasionally coded as non-specific for either injury type or site. No data on the use of safety restraints or protective equipment were collected. There is also a risk of exaggeration of effect with the use of odds ratio instead of relative risk, especially in cross-sectional studies where the outcome is not rare.²⁵ With severe outcomes identified in 38% of cases in our study, there is a tendency to overbias. The model derived may have been over-optimistic, and requires validation in another population.

Future studies on the impact of preventive measures such as the use of protective gear and safety advice are recommended. While out of the scope of this paper, examining injuries related to electronic-powered devices—including electronic bicycles, scooters, and hoverboards—would also be increasingly important with the rising popularity and potential high-speed injuries with such devices. Public and parental education is key in preventing additional injuries with a focus on appropriate age guidelines for each device, adequate supervision, and proper use of protective gear. This may be targeted at school-going children, users of skateboards, inline skates and scooters, and within public spaces such as playgrounds and sports facilities.

CONCLUSION

The use of non-motorised active mobility devices may result in severe injuries in children. Risk factors for severe injuries included school-going age, increased weight, location of the injury, and scooter, skateboard and inline skate use. The use of wrist and elbow guards, as well as helmets should be recommended, along with adequate parental supervision.

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