Hospital Seeing More Personal Mobility Device Accidents and Serious Injuries Despite Active Mobility Act

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Abstract

Introduction: E-scooters or personal mobility devices (PMDs) have recently been growing in popularity in Singapore. These devices can be especially helpful for those who have reduced mobility or who need to move between several relatively near locations multiples times per day or who simply appreciate the added convenience of having another transportation option. The increasing popularity of PMD has met with growing public concern over safety. Singapore government passed the Active Mobility Act (AMA) in January 2017 to regulate the usage of PMD. In Khoo Teck Puat Hospital, PMD-related accident has increased year on year by 20%-30%. Our study is to compare the incidence and severity of PMD-related accidents before and after the implementation of the AMA. Materials and Methods: A retrospective study of patients presented to the emergency department (ED) of Khoo Teck Puat Hospital for PMD-related accidents between November 2014 and October 2017. In year 1 of the study, we included patients presenting between November 2014 and October 2015. In years 2 and 3, we included patients presenting between November 2015 and October 2016 and November 2016 and October 2017, respectively. Data collected included demographic information, type of device used and impact, outcome, and injury severity score (ISS). Results: A total of 697 PMD-related accidents were seen in our center. We observed an increasing trend of accidents with significant injuries. There were 157 accidents reported in year 1, 233 in year 2, and 307 in year 3. The mean age of patients increased from 28 ± 15 years (range, 5–89 years) in year 1 to 33 ± 15 years (range, 4–83 years). Most patients were males (61.8% in year 1, 76.8% in year 2, and 73.3% in year 3) and Chinese (55.4% in year 1, 62.7% in year 2, and 65.5% in year 3), followed by Malays, Indians, and others. Devices commonly associated with injury were E-scooters, skateboards, and E-bicycles. E-scooters accidents had increased drastically from 12.1% in year 1 to 58.3% in year 3, but E-bicycles and other PMD accidents had decreased in year 3. Most patients were injured from falling off their devices (83.4% in year 1, 83.7% in year 2, and 79.5% in year 3), followed by collisions. Most patients arrived to the ED with own transports and were triaged to the patient acuity category 3 or 4. Most injuries were mild, with ISS <9 (97.5% in year 1 and 94.9% and 94.1% in year 2 and 3, respectively). The most common PMD-related injuries involved external injuries, followed by upper and lower extremities injuries. For more severe injuries (ISS ≥9), the number had increased from 4 in year 1 to 18 in year 3. Most patients were discharged. The number of patients required admissions increased from 12 to 44 in year 3, with two high-dependency or intensive care unit admissions. The mean hospital stay reduced from 5.0 ± 6.0 days to 3.6 ± 4.1 days, with the survival rate remained at 100%. There was only one fatality was reported in year 2. Conclusion: There is an increase in injuries and severity of PMD accidents despite AMA being implemented in January 2017. More need to be done to ensure the safety of PMD-related use in Singapore footpaths and roads.

Keywords: Accident, electric bicycles, personal mobility devices, scooters, trauma

Introduction

Personal mobility devices (PMDs) and electric bicycles (e-bikes) have become increasingly popular in Singapore in recent years. These increasingly popular PMDs provide portable personal transport to users in getting from one place to another quickly, particularly for short trips. Even the elderly welcome PMDs, which are in line with the government’s plan to encourage active mobility— reducing congestion on the roads while also promoting healthy behavior.[1] Unfortunately, the increase in active mobility uptake has been accompanied by concerns about path safety due to a rise in the number of accidents on public paths.

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has reported a threefold increase in PMD-related accidents between 2016 ($n = 46$) and 2017 ($n = 128$).[2] Statistics from the Land Transport Authority (LTA) showed that nearly a fifth of the 3700 active mobility offenses between May 2018 and April 2019 involved users who sped, rode recklessly, or used PMDs on roads. In 2017 and 2018, there were 228 reported accidents involving PMDs on public paths and 196 of them resulted in injuries.[3]

In January 2017, the government of Singapore passed the Active Mobility Act (AMA) to maintain and promote the safety of PMD usage.[4] In line with the government’s plans, the Safe Riding Programme was launched to put the public through a training circuit and familiarize them with the rules and codes of conduct under the AMA for PMDs.[5] A Safe Rider Campaign was also launched by Land LTA to promote safe riding behaviors for PMD riders.[6] LTA has been regulating the uses of PMD under the Act.[7]

In light of the spike in PMD-related accidents, our study aimed to compare the prevalence, patterns, and severity of PMD-related accidents before and after the implementation of the AMA.

**Materials and Methods**

A retrospective review of patients presenting to Khoo Teck Puat Hospital for PMD-related accidents from November 1, 2014, to October 31, 2017, was conducted. Patients who were injured from the use of PMDs or sustained injury as a result of a collision with another user of these mobility devices were included in this study. Injuries from nonpowered (conventional) bicycles and mobility aids (e.g., wheelchairs) were excluded from the study.

Information was gathered on patient demographics (age, gender, and ethnicity), type of mobility device used, type of impact, mode of transport to the emergency department (ED), total time in ED, hospitalization, survival rate, length of stay in the hospital, cost incurred during ED attendance and hospitalization, patient acuity category (PAC) scale, distribution of injury according to anatomical sites, and injury severity (based on the injury severity score [ISS]).

As defined by the Ministry of Health, Singapore, PAC 1 refers to patients with cardiovascular collapse or in imminent danger of collapse or who need to be attended to immediately; PAC 2 refers to patients who appear to be in a stable state upon initial cardiovascular examination and are not in danger of imminent collapse; however, they still require early attention due to the severity of their symptoms and possibly of early deterioration of condition; PAC 3 refers to patients with minor-to-moderate symptoms and are ambulatory; and PAC 4 are nonemergency cases that do not require immediate medical attention.

Data analysis was performed using a one-way analysis of variance for continuous data and a Chi-squared test for categorical data.

### Results

A total of 697 PMD-related accidents were seen in our center. Over the years, we observed an increasing trend of accidents with significant injuries. There were 157 accidents reported in year 1, 233 in year 2, and 307 in year 3. The mean age of patients increased from $28 \pm 15$ years (range, 5–89 years) in year 1 to $33 \pm 15$ years (range, 4–83 years). There was a male predominance (61.8% in year 1, 76.8% in year 2, and 73.3% in year 3) and Chinese as the majority of ethnic distribution (55.4% in year 1, 62.7% in year 2, and 65.5% in year 3), followed by Malays, Indians, and others [Table 1]. Devices commonly associated with injury were E-scooters, skateboards, and E-bicycles. E-scooters accidents had increased drastically from 12.1% in year 1 to 58.3% in year 3, but E-bicycles and other PMD accidents had decreased in year 3. Most patients were injured from falling off their devices (83.4% in year 1, 83.7% in year 2, and 79.5% in year 3), followed by collisions (12.1% in year 1, 12% in year 2, and 13.3% in year 3) [Table 2a]. There was an increasing number of patients ≥65-year-old sustained injuries from falling off their devices (1 patient in year 1, 3 in year 2, and 7 in year 3) [Table 2b].

Most patients arrived to the ED with their own transports (86.6 in year 1, 81.1% in year 2, and 81.4% in year 3) and had average time in ED of about 2–3 h. Most patients were discharged (92.4% in year 1, 87.1% in year 2, and 85.7% in year 3). Eight patients were discharged at their own risk and 7 were transferred to other hospitals. The remaining patients were admitted with an average length of hospitalization around

### Table 1: Baseline characteristics

| Parameter                     | Year 1 | Year 2 | Year 3 | P   |
|-------------------------------|--------|--------|--------|-----|
| Total enrolled patients       | 157    | 233    | 307    |     |
| Age group                     |        |        |        |     |
| Overall mean±SD-years*        | 28±15  | 32±15  | 33±15  | <0.01|
| Median age (years)†           | 24     | 28     | 31     |     |
| Age range (years)             | 5–89   | 4–84   | 4–83   |     |
| <15                           | 24 (15.3) | 22 (9.5) | 17 (5.5) | <0.01|
| 15−24                         | 57 (36.3) | 72 (30.9) | 81 (26.4) | 0.08|
| 25−34                         | 28 (17.8) | 59 (25.3) | 83 (27.0) | 0.08|
| 35−44                         | 29 (18.5) | 32 (13.7) | 70 (22.8) | 0.03|
| 45−54                         | 9 (5.7) | 28 (12.0) | 26 (8.5) | 0.09|
| 55−64                         | 6 (3.8) | 13 (5.6) | 19 (6.2) | 0.57|
| ≥65                           | 4 (2.6) | 7 (3.0) | 11 (3.6) | 0.82|
| Gender                        |        |        |        |     |
| Female                        | 60 (38.2) | 54 (23.2) | 82 (26.7) | <0.01|
| Male                          | 97 (61.8) | 179 (76.8) | 225 (73.3) |     |
| Race                          |        |        |        |     |
| Chinese                       | 87 (55.4) | 146 (62.7) | 201 (65.5) | 0.11|
| Malay                         | 38 (24.2) | 59 (25.3) | 71 (23.1) | 0.84|
| Indian                        | 12 (7.7) | 13 (5.6) | 19 (6.2) | 0.71|
| Others                        | 20 (12.7) | 15 (6.4) | 16 (5.2) | 0.01|

*Data presented as mean±SD. †Data presented as median (range). SD: Standard deviation.
3.6–5.0 days and the average hospital bill ranged from SGD 2889 to SGD 5432. Most patients were admitted to the general ward (83.3% in year 1, 86.7% in year 2, and 95.5% in year 3). The survival rate remained at 99.6% to 100% [Table 3].

Most patients were triaged to PAC 3 or 4 (82.8% in year 1, 84.1% in year 2, and 74.3% in year 3) [Table 4]. Most injuries were mild, with ISS <9 (97.5% in year 1 and 94.9% and 94.1% in year 2 and 3, respectively). The mean ISS ranged from 2.1 to 2.9. The most common PMD-related injuries involved external injuries (73.2% in year 1, 87.6% in year 2, and 82.4% in year 3), followed by upper and lower extremities injuries. For more severe injuries (ISS ≥9), the number of cases had increased from 4 in year 1 to 18 in year 3. There was only one case of fatality related to PMD reported in 2016, the cause of death was secondary to severe head injury and hemorrhage from collision with a lorry [Table 5].

**Discussion**

PMD-related accidents highlight a significant public health issue. In an effort to regulate the sale and usage of PMDs in the country, the Singapore government passed the AMA in January 2017. Since May 2018, the LTA has been regulating the use of PMDs under the Act. The rising incidence could be explained by the rapid adoption of PMDs and the recent introduction of safety regulations mandated by the government. It was also contributed by a lack of public awareness of the use of PMDs.

Considering the demographics of PMD-related injuries reflected in this study, injury prevention efforts should be targeted at those aged 4–89 years. Interestingly, the use of PMD in the elderly population is increased, they may use it due to their reduced walking ability and convenience or affordability of PMD. The ethnic distribution of the cases was largely similar to Singapore’s population demographics, with the majority being Chinese.

In our study, devices commonly associated with injury were E-scooters, skateboards, and E-bicycles. E-scooter accidents were significantly increased from 12.1% to 58.3% within 3 years. It could be largely contributed by the rising use of PMDs. More than 75,000 e-scooters have been registered with LTA. A majority of 73% between the ages of 21 and 50.

### Table 2a: Type of mobility device used and impact

| Parameter | Year 1 | Year 2 | Year 3 | P  |
|-----------|--------|--------|--------|----|
| Total enrolled patients | 157 | 233 | 307 |    |
| Motorized device |        |        |        |    |
| E-scooter | 19 (12.1) | 68 (29.2) | 179 (58.3) | <0.01 |
| E-bike | 27 (17.2) | 30 (12.9) | 23 (7.5) | <0.01 |
| Other* | 5 (3.2) | 13 (5.6) | 24 (7.8) | 0.13 |
| Nonmotorized device |        |        |        |    |
| Nonmotorized scooter | 30 (19.1) | 41 (17.6) | 29 (9.5) | <0.01 |
| Skateboard | 48 (30.6) | 45 (19.3) | 32 (10.4) | <0.01 |
| Other† | 28 (17.8) | 36 (15.4) | 20 (6.5) | <0.01 |
| Type of impact |        |        |        |    |
| Fall off PMD/e-bike | 131 (83.4) | 195 (83.7) | 244 (79.5) | 0.38 |
| Collision with ≥4-wheel vehicle | 7 (4.5) | 14 (6.0) | 20 (6.5) | 0.67 |
| Collision with stationary object | 6 (3.8) | 10 (4.3) | 13 (4.2) | 0.97 |
| Collision with human | 2 (1.3) | 3 (1.3) | 1 (0.3) | 0.40 |
| Collision with another PMD/4-wheel vehicle | 4 (2.5) | 1 (0.4) | 7 (2.3) | 0.17 |
| Injury sustained when someone else using PMD | 7 (4.5) | 10 (4.3) | 22 (7.2) | 0.28 |

*Refers to electric unicycles and skateboards. †Refers to hoverboards, nonmotorized unicycles, roller blades, waveboards, and longboards. E-bike: electric bicycle; PMD: Personal mobility device, SD: Standard deviation.

### Table 2b: Type of impact in patients ≥65 years old

| Type of impact | Year 1 (n=4) | Year 2 (n=7) | Year 3 (n=11) |
|---------------|--------------|--------------|---------------|
| Fall off PMD/e-bike | 1 | 3 | 7 |
| Collision with ≥4-wheel vehicle | 1 | 1 | 1 |
| Collision with stationary object | | | |
| Collision with human | | | |
| Collision with another PMD/4-wheel vehicle | | | |
| Injury sustained when someone else using PMD | 2 | 2 | 3 |

PMD: Personal mobility device.
The vast majority of injuries were sustained from falling off their devices, followed by collisions. Patients were mainly treated in an ambulatory setting. Injuries were typically minor, comprising of external injuries. This finding is consistent with general literature.\[11\] Physical conditions such as lighting and the conditions of road and paths should be evaluated as injury prevention measures. PMD riders are subject to inevitable lags in reaction times when stopping, pointing to a high likelihood of a collision, especially in narrow walkways. The revision of the speed limit for PMDs on footpaths from 15 km/h to 10 km/h is effective after February 1, 2019, in the effort of reducing the incidence of accidents by allowing path users more time to react.\[12\]

Besides a spike in the number of PMD-related accidents, there was also a rise in the severity of injuries (higher ISS score). The rise could be related to multiple regions of trauma. Although the mean inpatient stay and average hospital bill decreased in year 3, it did not include the period of rehabilitation for functional recovery. In our study, there was one fatality reported. The cause of death was due to severe head injury and hemorrhage. Out of 142 posted reports of road traffic accident deaths recorded in Windsor, the most common cause of death was intracranial hemorrhage and severe head injury which contributed to 32.5% of total cases.\[13\] Intracranial hemorrhage causes compression to adjacent brain tissues, leading to neurological dysfunction and potential fatal herniation syndrome. A literature done in China reported the failure to wear helmets is one of the most common reasons that has been attributed to the rise in PMD-related injuries in China.\[14\] Helmet use should be enforced to reduce the risks of head-and-neck injury.

### Table 3: Processes and outcome

| Parameter | Year 1 | Year 2 | Year 3 | P |
|-----------|--------|--------|--------|---|
| Total enrolled patients | 157 | 233 | 307 | |
| Mode of arrival to ED | | | | |
| Ambulance/nonstandby | 20 (12.8) | 42 (18.0) | 53 (17.3) | 0.34 |
| Ambulance/standby | 1 (0.6) | 2 (0.9) | 4 (1.3) | 0.76 |
| Own transport | 136 (86.6) | 189 (81.1) | 250 (81.4) | 0.30 |
| Total ED time (min) | 159±86 | 171±126 | 184±127 | 0.086 |
| Hospitalisation | | | | |
| Yes | 12 (7.6) | 30 (12.9) | 44 (14.3) | 0.11 |
| General ward | 10 (83.3) | 26 (86.7) | 42 (95.5) | 0.28 |
| HD/ICU | 2 (16.7) | 4 (13.3) | 2 (4.5) | |
| No | 145 (92.4) | 203 (87.1) | 263 (85.7) | 0.11 |
| Transferred to other hospital | 4 (2.8) | 2 (1.0) | 1 (0.4) | 0.09 |
| Discharged at own risk | 3 (2.1) | 4 (2.0) | 1 (0.4) | 0.21 |
| Survival rate (%) | 157 (100) | 232 (99.6) | 307 (100) | 0.37 |
| Hospital length of stay (day) | 5.0±6.0 | 3.4±4.1 | 3.6±4.1 | 0.534 |
| Duration of medical leave (day) | 5.0±5.7 | 6.9±7.0 | 7.3±7.5 | <0.01 |
| Mean bill size (SGD) | | | | |
| ED | 129±98 | 143±132 | 132±70 | 0.357 |
| ED + hospitalization | 5432±10099 | 2491±3176 | 2889±3582 | 0.198 |
| Total costs for the whole year (SGD) | 83,860.76 | 103,807.18 | 161,930.95 | |

ED: Emergency department, HD/ICU: High-dependency unit/intensive care unit, SD: Standard deviation

### Table 4: Injury severity and distribution

| Parameter | Year 1 | Year 2 | Year 3 | P |
|-----------|--------|--------|--------|---|
| Total enrolled patients | 157 | 233 | 307 | |
| PAC at triage* | | | | |
| 1 | 3 (1.9) | 4 (1.7) | 11 (3.6) | 0.33 |
| 2 | 24 (15.3) | 33 (14.2) | 68 (22.1) | 0.03 |
| 3 or 4 | 130 (82.8) | 196 (84.1) | 228 (74.3) | 0.01 |
| Mean ISS | 2.1±2.9 | 2.9±4.0 | 2.7±2.6 | 0.037 |
| Median (range) ISS | 1 | 1 | 1 | |
| ISS tier | | | | |
| 1 (<15) | 1 (0.6) | 4 (1.7) | 1 (0.3) | 0.21 |
| 2 (9–15) | 3 (1.9) | 8 (3.4) | 17 (5.6) | 0.15 |
| 3 (<9) | 153 (97.5) | 221 (94.9) | 289 (94.1) | 0.28 |
| Probability of survival (%) | | | | |
| Mean | 99.5±0.5 | 99.1±5.9 | 99.5±0.6 | 0.279 |
| Median | 99.7 | 99.7 | 99.7 | |
| Site of injury* | | | | |
| Head | 4 (2.5) | 15 (6.4) | 11 (3.6) | 0.13 |
| Face | 9 (5.7) | 16 (6.9) | 23 (7.5) | 0.78 |
| Thorax | 3 (1.9) | 6 (2.6) | 8 (2.6) | 0.89 |
| Abdomen | 1 (0.6) | 1 (0.4) | 1 (0.3) | 0.89 |
| Pelvis | 3 (1.9) | 1 (0.4) | 0 | |
| Spine/spinal column | 0 | 1 (0.4) | 1 (0.3) | 0.03 |
| Upper limb | 37 (23.6) | 60 (25.8) | 90 (29.3) | 0.38 |
| Lower limb | 22 (14.0) | 20 (8.6) | 43 (14.0) | 0.12 |
| External | 115 (73.2) | 204 (87.6) | 253 (82.4) | <0.01 |

*As defined by the Ministry of Health, Singapore. The percentages do not add up to 100% because one patient may not have more than one region of injuries. ISS: Injury severity score, PAC: Patient acuity category, SD: Standard deviation
AMA came in force to provide a set of rules and regulations to enable safer sharing on public paths. Criteria for PMD were revised as follows: (i) weight must be ≤20 kg to reduce the risk of serious injuries in cases of collision, (ii) width must be ≤70 cm to allow devices to collide each other safely, (iii) motorized device speed must be capped at maximum 25 km/h to ensure the users do not exceed the speed limit, and (iv) Motorized PMDs must be certified to a device safety standard UL2272 to address fire incidents and improve public safety.[15] Users will face penalties if they are caught riding a PMD that does not meet the criteria above. Users should ensure their PMDs are in good working condition before riding on path. They are advised to keep a safe distance from other path users, stop and look for oncoming traffic before riding across the road to avoid the collision.

The limitation of our study includes the data extraction of PMD-related accidents seen in a single institute, which could limit its generalizability. The severity of injuries sustained from motorized devices compared to that from nonmotorized devices was not highlighted. Other relevant data points such as the use of helmets and location (footpath, cycling path, or road) where these injuries happen are also not captured. This would also make it difficult to spot trends in the injuries and to assess the adequacy and efficacy of current public education efforts and preventive measures.

**Conclusion**

There is a worrying trend of increased accidents and serious injuries related to PMD use from the year 2014 to 2017. The rise of such accidents is increasingly contributing to the health-care burden with socioeconomic consequences associated with them. This study contributes to the understanding of the injury incidence and severity of PMD-related accidents before and after the implementation of the AMA in Singapore.

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**Conflicts of interest**

There are no conflicts of interest.

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