Patterns of orthopaedic injury among hospitalised personal mobility device users and bicycle riders: a comparative study

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ABSTRACT

Introduction: Personal mobility devices (PMDs), such as electronic scooters or motorised bicycles, are efficient modes of transportation. Their recent popularity has also resulted in an increase in PMD-related injuries. We aimed to characterise and compare the nature of injuries sustained by PMD users and bicycle riders.

Methods: This retrospective study compared injury patterns among PMD and bicycle users. 140 patients were admitted between November 2013 and September 2018. Parameters studied included patients’ demographics (e.g. age, gender and body mass index), type of PMD, nature of injury, surgical intervention required, duration of hospitalisation and time off work.

Results: Of 140 patients, 46 (32.9%) patients required treatment at the department of orthopaedic surgery. 19 patients were PMD users while 27 were bicycle riders. 16 (84.2%) patients with PMD-related injuries were men. PMD users were significantly younger (mean age 45 ± 15 years) when compared to bicycle riders (mean age 56 ±17 years; p < 0.05). A quarter (n = 5, 26.3%) of PMD users sustained open fractures and over half (n = 10, 52.6%) required surgical intervention. Among 27 bicycle users, 7.4% (n = 2) of patients sustained open fractures and 70.4% (n = 19) required surgical intervention. Both groups had comparable inpatient stay duration and time off work.

Conclusion: PMD-related orthopaedic traumas are high-energy injuries, with higher rates of open fractures, when compared to bicycle injuries. In addition, PMD users are significantly younger and of economically viable age. Prolonged hospitalisation and time off work have socioeconomic implications. Caution should be exercised when using PMDs.

Keywords: bicycle injuries, open fractures, personal mobility device, public health, trauma
INTRODUCTION

Personal mobility devices (PMDs) are efficient modes of transportation, allowing users speedy commute. PMDs range from one-wheeled self-balancing unicycles and self-balancing hoverboards to two-wheeled electric scooters. In the existing literature, some authors have considered electric bicycles (or e-bikes) as PMDs as well. However, due to their size, road-worthiness and potential to travel further, e-bikes have also been classified as powered-assisted bicycles in certain countries.\(^{(1)}\)

The popularity of PMD use has risen exponentially over the last decade, especially within Asia. Driven by the rapid urbanisation of cities and greater transport connectivity, PMDs have become an attractive mode of compact, last-mile transport for city dwellers.\(^{(2-4)}\)

In addition, with increasing awareness of one’s carbon footprint and the push for ‘greener’ technologies, coupled with improving infrastructure (e.g. charging points and shared pathways) to support such transport, riders find this novel mode of transport practical and efficient.\(^{(4-6)}\)

As its popularity as a mode of transport rises, so does the incidence of PMD-related accidents.\(^{(7-9)}\) Between 2015 and 2017, PMD-related accidents in Singapore have more than doubled year-on-year from 19 incidents in 2015 to 46 in 2016 and 128 incidents in 2017.\(^{(8)}\) This is despite the Singapore government taking prompt steps in enforcement, through the establishment of the Active Mobility Advisory Panel, to safeguard commuting space for PMD riders and the public at large.\(^{(1)}\)

In view of this growing public safety risk, we were of the opinion that the subject warranted further consideration – especially from an orthopaedic point of view. By characterising the nature of injuries among PMD users and bicycle riders, we hope to aid in the formalisation of better legislation to safeguard the wellbeing of riders and the public alike.
Accordingly, the present study aimed to characterise the nature of injuries sustained among hospitalised PMD users and bicycle riders.

METHODS

This was a single-centre retrospective study that was approved by the hospital’s ethics committee (CIRB: 2018/2656) and carried out in accordance with the ethical standards laid down in the 1964 Declaration of Helsinki.

Between November 2013 and September 2018, 140 patients with PMD- or bicycle-related injuries were admitted to the Singapore General Hospital, Singapore (Fig. 1). Among these patients, 19 PMD-related injuries and 27 bicycle injuries fulfilled both inclusion and exclusion criteria, and were treated at the department of orthopaedic surgery.

For the purpose of this study, PMDs were defined as any mobility device (e.g. manually propelled skate scooters, electric hoverboards, self-balancing unicycles, Segways and electronic scooters) that is allowed for use along footpaths and shared pathways but not on the roads. Road-worthy e-bikes were therefore excluded. In addition, personal mobility aids, such as those used by disabled people, were also excluded.

Bicycle-related injuries were either vehicular-related road traffic accidents or non-vehicular injuries occurring along shared or bicycle pathways. To allow accurate assessment and comparison, only non-vehicular injuries were studied.

Factors, such as age, gender, body mass index (BMI), mechanism of injury, surgical intervention required, number of surgical interventions, hospitalisation stay and time off work, were studied. Duration of continuous hospitalisation leave was used as a surrogate indicator for time off work.

Statistical analysis was carried out using IBM SPSS Statistics version 19.0 (IBM Corp, Armonk, NY, USA). Student’s unpaired t-test was used for continuous variables (e.g. age, body
mass index, hospitalisation duration and time off work) and Pearson’s chi-square test was used for categorical variables (e.g. gender, need for surgery and open fractures). Statistical significance was defined as $p \leq 0.05$.

RESULTS

A total of 19 and 27 patients with PMD- and bicycle-related injuries, respectively, who met both the inclusion and exclusion criteria, were admitted to the Department of Orthopaedic Surgery at the Singapore General Hospital, Singapore, between 2013 and 2018 (Fig. 2).

Among patients with PMD-related injuries ($n = 19$), 16 (84.2%) were men. Mean age of PMD users was $45 \pm 15$ years (Table I). A majority of patients had lost control of their device and fallen ($n = 15$, 78.9%), while the remaining had collided with an obstacle ($n = 4$, 21.1%) (Fig. 3). A quarter of patients with PMD-related injuries ($n = 5$, 26.3%) had open fractures, with 10 (52.6%) patients requiring surgical intervention. 2 (10.5%) patients in the PMD group did not benefit from surgical intervention due to high surgical risk from multiple comorbidities and financial constraints. Patients had injuries of the upper limb ($n = 7$, 36.8%), lower limb ($n = 13$, 68.4%) and involving the spine ($n = 1$, 5.3%). The average length of hospital stay was $8 \pm 9$ days and the average time off work was $76 \pm 52$ days (Table II).

Table I. Patient demographics.

<table>
<thead>
<tr>
<th>Variable</th>
<th>No. (%)</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (yr)*</td>
<td>45 ± 15</td>
<td>0.017†</td>
</tr>
<tr>
<td></td>
<td>56 ± 17</td>
<td></td>
</tr>
<tr>
<td>Gender</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Men</td>
<td>16 (84.2)</td>
<td>-</td>
</tr>
<tr>
<td>Women</td>
<td>3 (15.8)</td>
<td>-</td>
</tr>
<tr>
<td>Body mass index (kg/m²)*</td>
<td>23.0 ± 4.1</td>
<td>0.295</td>
</tr>
<tr>
<td></td>
<td>25.0 ± 6.5</td>
<td></td>
</tr>
</tbody>
</table>

*Data presented as mean ± standard deviation. †$p < 0.05$ was statistically significant. PMD: personal mobility device
Table II. Comparison between PMD and bicycle users.

<table>
<thead>
<tr>
<th>Variable</th>
<th>No. (%)</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Open fracture</td>
<td>PMD users (n = 19)</td>
<td>Bicycle riders (n = 27)</td>
</tr>
<tr>
<td></td>
<td>5 (26.3)</td>
<td>2 (7.4)</td>
</tr>
<tr>
<td>Location of fracture</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Upper limb</td>
<td>7 (36.8)</td>
<td>7 (25.9)</td>
</tr>
<tr>
<td>Lower limb</td>
<td>13 (68.4)</td>
<td>14 (51.9)</td>
</tr>
<tr>
<td>Spine</td>
<td>1 (5.3)</td>
<td>6 (22.2)</td>
</tr>
<tr>
<td>Surgical intervention required</td>
<td>10 (52.6)</td>
<td>19 (70.4)</td>
</tr>
<tr>
<td>Length of hospital stay (day)*</td>
<td>8 ± 9</td>
<td>9 ± 7</td>
</tr>
<tr>
<td>Time off work (day)*</td>
<td>76 ± 52</td>
<td>73 ± 98</td>
</tr>
</tbody>
</table>

*Data presented as mean ± standard deviation. PMD: personal mobility device

All bicycle riders were men, with a mean age of 56 ± 17 years (Table I). Among these, 19 (70.3%) patients reported falling off their bicycle; 4 (14.8%) patients reported colliding with an obstacle and 3 (11.1%) patients collided with a pedestrian (Fig. 3). Among bicycle riders, 19 (70.4%) patients required surgical intervention. Only 2 (7.4%) patients had open fractures. A majority of injuries involved the lower limb (n = 14, 51.9%); there were 7 (25.9%) patients with upper limb injuries and 6 (22.2%) patients with injuries involving the spine. The average length of hospital stay for bicycle riders was 9 ± 7 days and average time away from work was 73 ± 98 days (Table II).

PMD users were significantly younger when compared to bicycle riders (p < 0.05) and had a greater proportion of open fractures (PMD users vs. bicycle riders: 26.3% vs. 7.4%, p = 0.091), although the latter was not statistically significant.

**DISCUSSION**

Similar to the existing literature on e-bikes and PMD use, PMD-related injuries in our study showed a strong male predominance. The mean age of PMD users was significantly lower when compared to that of conventional cyclists. This can be attributed to the greater appeal that PMDs hold for young people when compared to the use of bicycles. This was also
significant because the mean age of PMD users with injuries fell within the age groups in the active workforce in Singapore.\(^{(10)}\)

A striking finding in our study was that PMD-related injuries resulted in a higher proportion of open fractures when compared to bicycle use. The added soft tissue injuries sustained were indicative of higher energy injury.\(^{(11,12)}\) A look at the mechanism of injuries indicated that PMD users either were travelling at high speeds or lacked control of the PMD at the time of accident, thereby not being able to slow down enough to avert the incident. Of the five patients with open fractures in the PMD group, four patients had injuries involving the upper limb, suggesting that these users were attempting to break their fall.

Injuries for PMD users affected either the upper or lower limbs, with less injury involving the spine. In comparison, bicycle riders had a greater proportion of spinal injuries. This may suggest that with conventional bicycles, attempts to brake at high speeds can sometimes result in the cyclists being thrown over, thereby accounting for a higher number of burst or compression fractures in this group. The high number of spinal injuries associated with bicycle riders was associated with serious sequelae, including one death, one patient with tetraplegia and one patient with residual hearing loss due to concomitant neurological injuries. For one bicycle rider, injury was caused by the collapse of a tree onto the rider and not vice versa.

The healthcare cost and economic burden associated with injuries among PMD users is significant. As the number of users continues to grow, it is a valid cause for concern.\(^{(7)}\) Despite comparable hospital stay and time away from work between the two patient groups, the time away from the workforce was nevertheless considerable. Regulators thus should strive to find a balance between policies restricting this novel mode of transport and ensuring the safety of PMD riders and the public at large.
The aim of this study was to characterise the type of injuries sustained by PMD users. It allowed better appreciation of the demographics of PMD users, the nature of their injuries as well as the considerable downtime associated with these injuries. We were of the opinion that related data would shed light on this growing healthcare concern\(^{(8)}\) as well as provide clinical evidence to help shape public safety policies, infrastructure planning, effective enforcement of PMD use and reducing the number of PMD-related injuries.

The Active Mobility Act of 2017 in Singapore\(^{(13)}\) set a good precedence to regulating PMD use. In accordance with the Act, speeds of PMD were restricted to 25 km/hour on shared pathways and 15 km/hour on footpaths. This speed was further reduced to 10 km/hour on footpaths following a review by the Active Mobility Advisory Panel in September 2018.\(^{(14)}\) Limiting the speed of PMDs will definitely serve to reduce the numbers of high-energy injuries sustained by PMD users. The size and weight of the PMD was also restricted to 70 cm in width and a maximum of 20 kg, respectively.\(^{(1)}\) In addition, it also enforced that PMDs not be used on the roads and encouraged better visibility through the use of rear reflectors and front lights. There is extensive literature highlighting the reckless application of these mobility devices.\(^{(3,8,15,16)}\) In Singapore, recent legislative changes have been put in place to create greater accountability and compliance among PMD users – through limitation of the maximum speed a device can achieve, compulsory registration of the mobility devices and potential criminal implications for convicted negligent users. These are good starting points to aid better PMD use, ensuring the safety of both riders and the public at large, in view of the shared space between both parties. The full effect of this Act is yet to be fully appreciated in view of its recent enforcement on 1 February 2019. A follow-up study comparing injury patterns and incidence after this date may provide insight into the efficacy of these legislative measures.

Further studies involving multiple centres and a greater number of patients are warranted to better understand PMD-related injuries. The authors recommend that a national
trauma registry be established for PMDs and e-bikes to facilitate future prospective studies. Parameters crucial for recording among patients sustaining related injuries should include basic demographic data, in addition to the nature and mechanism of injury, its complications, intervention performed, duration of hospitalisation, time off work and the use of protective gear. Last but not the least, we suggest a standardisation of the definition for what qualifies as a PMD within the literature, so as to facilitate future reviews. This is particularly pertinent as some roadworthy e-bikes capable of achieving significantly greater speeds may present with a different spectrum of injuries.

There were limitations to our study. Firstly, there were likely inherent selection and observer biases, as the patients were recruited from a single tertiary hospital. Future multicentre trials, or the use of a national registry, in view of this growing healthcare concern, would reduce these. Secondly, the design of this study was retrospective in nature. To the best of our knowledge, this was a pioneering study comparing the injury patterns and potential healthcare burden of PMD-related injuries (excluding e-bikes) with bicycle-related injuries. Future prospective studies exploring these are warranted. Thirdly, there was limited information on the injuries sustained by pedestrians as a result of PMD accidents. This was a limitation in our single-centre study, as these victims were likely to have been managed at another institution. This is another group of patients that the national registry for PMDs and e-bikes should consider including.

In conclusion, PMDs are transportation aids that are rapidly influencing the way people get about. Its use and application will only continue to grow, especially with increasing urbanisation. This study demonstrated that PMD-related injuries were associated with a significantly younger population, with higher rates of open fractures, when compared to bicycle accidents. PMD-related injuries were also associated with prolonged hospital stay and time off
work. Caution should be exercised with PMD use, and the legislation limiting its speed limits and appropriate use should not go unheeded.

REFERENCES


FIGURES

**Fig. 1** Distribution of care for patients hospitalised with PMD- and bicycle-related injuries.

Note: A third of our patients required orthopaedic intervention and care.
Fig. 2 Patient cohort flowchart showing inclusion and exclusion criteria and data collection.

BMI: body mass index
Fig. 3 Mechanism of injury among patients with PMD- and bicycle-related injuries. PMD: personal mobility device