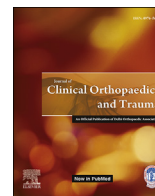




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The Orthopedic Injury Burden of Personal Mobility Devices in Singapore – Our Experience in the East Coast

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ABSTRACT

Purpose: Personal mobility devices (PMDs) have become increasingly popular as a modality of transport worldwide. Starting out as novelty toys, PMDs are gradually being adopted as the mainstream mode of travel. There is an increasing number of accidents involving both PMD riders and other road users since its introduction, leading to a concomitant increase in demand for healthcare resources to manage the injuries. The main objective of this study was to evaluate the inpatient cost and the orthopedic injury pattern due to PMD accidents.

Methods: All patients admitted to the Department of Orthopedic Surgery between December 2016 to February 2018 with injuries due to PMD accidents were recruited. Data collection was performed retrospectively on the demographic profiles, injury patterns, admission related outcomes and expenditures of these patients.

Results: 43 patients were included in this study. The mean duration of admission was 7.81 days and the median cost of admission was S\$7835.01 (approximately US\$5620). These were comparable to accidents arising from other modes of transport, such as motorcycles and bicycles. In addition, more than 80% of patients were not wearing protective gear at time of accident. These patients had a slightly higher median cost payable per patient as compared to those who donned protective gear, with a difference of S\$1669.78 (approximately US\$1221).

Conclusion: There is a significant health and financial cost to the individual and society from PMD injuries and admission. This can be reduced with strict regulations on PMD use, advocating protective gear use, and promoting awareness on safety measures and the consequences of PMD accidents. The most common injury mechanism and orthopedic injury type for PMD accidents are different from motorcycle accidents.

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1. Introduction

Personal mobility devices (PMDs) have become increasingly popular as a modality of transport worldwide. Starting out as novelty toys, PMDs are gradually being adopted as the mainstream mode of travel. They are able to travel long distances, and provide an environmentally friendly alternative to motorcycles and cars due to their low energy consumption. In a bid to reduce traffic volume in the urban setting and make these devices more accessible, e-bike and e-scooter rental services have been introduced to various cities worldwide. However, given the current infrastructure

and to avoid motor vehicles on the roads, PMD users utilize the pedestrian sidewalks and common corridors of buildings.¹ In turn, there has been an associated increase in the number of collisions between pedestrians and PMD users.²

In Singapore, PMDs have not been made available via rental services. Most users own personal PMDs. Its use is especially popular in the food delivery service. There is an increasing number of accidents involving both PMD riders and other road users^{3,4} since its introduction. This is associated with a concomitant increase in demand for healthcare resources to manage the injuries. In a bid to reduce the number of PMD accidents, the Singapore government introduced the Active Mobility Act (AMA)⁵ in May 2018 to regulate PMD sales and their use on common footpaths. PMD users who do not abide by the directives of the AMA would face prosecution. The main objective of this study was to evaluate the inpatient cost and

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Abbreviations

PMD	Personal mobility devices
AMA	Active Mobility Act
HD	High dependency
ICU	Intensive care unit

orthopedic injury pattern of patients admitted to the Department of Orthopedic Surgery in a tier 2 trauma center following PMD-related injuries in the 15 months before the AMA.

2. Methods

This is a retrospective observational study. The waiver of informed consent by institutional review board was granted as only retrospective and de-identified data was used.

Between December 2016 to February 2018, all patients admitted to the Department of Orthopedic Surgery with injuries associated with PMD accidents such as e-scooter, e-bikes, electric hoverboards and electric mono-wheels were entered into a registry. All admissions over the study period were reviewed daily and the suitable patients were identified. The registry included patients admitted from the Emergency Department and the Orthopedic specialist outpatient clinic. The patients with PMD injuries who were admitted under other specialties, who did not survive, who received only outpatient treatment were excluded from the study.

The demographic details of the subjects, type of road user, circumstances of accident, mechanism, severity, and nature of injuries of the subjects were collated. The details on nature of injury comprised the region of body affected, number of fractured bones, open or closed nature of fractures. The length of hospital stay, number of hospital admissions, type of bed occupied (general ward, high dependency (HD) or intensive care unit (ICU) bed), surgical management and number of surgeries (if any) as well as discharge destination were collated. The cost analysis included total overall cost of admission and cost payable by patient after government subsidies.

After tabulation of results, data analysis was performed using IBM SPSS Statistics 20.0 software.

3. Results

During the study period from December 1, 2016 to February 28, 2018, 43 patients with PMD-related injuries were admitted to the Department of Orthopedic Surgery. 38 patients (88.3%) were involved with accidents related to e-scooters. Of the remaining 5 patients, 2 patients (4.7%) had accidents involving e-bikes, 2 patients (4.7%) had accidents involving electric hoverboards and 1 patient (2.3%) had an accident involving the electric mono-wheel. 40 out of 43 patients (93%) were riders, 2 patients (4.7%) were pillion riders and 1 patient (2.3%) was a pedestrian.

The majority of the patients were male ($n = 36$, 83.7%) and of Chinese race ($n = 31$, 72.1%). Most of the patients were age 40 years or younger ($n = 29$, 67.3%). Only 8 patients (18.6%) were wearing protective gear at time of accident. Most injuries were sustained from self-skidding. 37 patients (86%) sustained fractures and 15 patients (34.9%) had multiple fractures (more than 1 bone broken), with 34 patients (77%) requiring surgical intervention. The mean duration of admission was 7.81 days. The median cost of admission was S\$7835.01 (approximately US\$5620). Most patients were managed in the general ward and more than 90% did not require further institutionalization after treatment in an acute hospital.

Analysis of variables that could have affected total cost of admission was performed, as shown in Table 1.

4. Discussion

Road traffic accidents account for up to 1.2 million deaths worldwide annually and for 20–50 million injuries or disabilities.^{6,7} Previously, these included accidents involving motor vehicles such as cars, motorcycles, cyclists and pedestrians. Literature evaluating the injury patterns and outcomes of road traffic accidents involving motor car drivers and motorcycle riders are widely available. Majority of patients were young, with mean ages of patients involved in motorcycle accidents ranging between 20 and 30 years old.^{8–11} The gender distribution of patients with PMD-related injuries were also similar to those in studies of motorcycle-related injuries, as shown in Table 2.

Multiple fractures were common in patients involved in motorcycle accidents, with incidences ranging from 20 to 40%.^{12,13} Mean duration of admission ranged from 5 to 10 days. Our study found similar incidences of compound fractures and length of stays despite our study population involving only accidents involving PMD-related accidents, suggesting that these devices may cause orthopedic injuries of similar severity as motor vehicles.

Between 1985 and 1987, at least US\$29 million was spent on motorcycle injuries¹⁴ in the United States of America (USA). Over US\$13.3 billion was spent on 3.75 million cases non-fatal bicycle crashes requiring admission¹⁵ in the USA from 1997 to 2013. Between 2002 and 2011, annual total medical cost of orthopedic inpatients involved in traffic accidents in Taiwan ranged between US\$45.6 million to US\$86 million.¹⁶ In 2010, US\$295 million was spent on medical care for patients involved in over 800,000 road traffic accidents¹⁷ in Iran. In 2018, a grand total of US\$51.2 billion was spent on medical expenses from 4.5 million medically consulted injuries arising as a result of road traffic accidents¹⁸ involving motor vehicles in the USA. Clearly, there is significant economic burden arising as a result of traffic accidents involving vehicles of all forms worldwide. The increasing use of PMD is likely to contribute to this financial burden as well.

In Singapore, there were 124 cases of fatalities out of a total of 7690 road traffic accidents in 2018 with a 2.2% fatality rate per 100,000 population.^{19,20} At least 200 accidents reported were involving PMDs. The current study described 43 patients with orthopedic injuries warranting admission. The median total cost of admission per patient was S\$7835.01 (approximately US\$5620). The median gross monthly income of full-time employed Singapore residents ranged from S\$4056 – S\$4437 between 2016 to 2018.²¹ This meant that a patient who required admission for orthopedic injuries as a result of a PMD-related accident could be spending almost two months' worth of wages on medical treatment. For now, the cost of admission per patient is low when compared to patients with injuries sustained from accidents involving other modes of transport in other countries as seen from Table 3. Approximately S\$1.5 million (US\$1.08 million) was spent on PMD-related injuries in the year 2018, comparable to that in Auckland, where NZ\$1.27 million (approximately US\$817817) was spent on e-scooter related injuries just over a 6-month period²² between September 2018 to April 2019. The current finding is high compared to that by Miki,¹¹ who observed the estimated R\$1101028.71 (US\$210430) was low due to subsidy. The current finding is purely the cost of admission and does not include costs incurred at follow-up visits. The patients also sustained productivity and economic losses. When the healthcare and societal costs is factored into the analysis, the actual total cost is expected to be higher than values presented.

Campbell et al. evaluated the cost of e-scooter related orthopedic injuries requiring surgical intervention in Auckland.²⁴ 23

Table 1
Cost of hospitalization against various determining factors.

Variable	No. (%) of patients	Median (Inter-Quartile Range) for Cost of Admission (\$\$)
Age		
40 or younger	29 (67.4)	8912.96 (5406.79–17464.28)
Above 40	14 (32.6)	6276.92 (408.85–8290.41)
Sex		
Male	36 (83.7)	7738.09 (3492.52–13666.47)
Female	7 (16.3)	7835.01 (371.18–17214.27)
Crash Type		
Self-skidded	31 (72.1)	8281.02 (2917.24–17214.27)
Collision	12 (27.9)	5935.91 (444.40–9334.88)
Wearing Protective Gear		
Yes	8 (18.6)	6568.79 (1933.81–11182.61)
No	35 (81.4)	8238.57 (2397.01–16141.13)
Injury		
Fracture	37 (86.0)	6782.02 (1469.49–12535.70)
No fracture	6 (14.0)	14307.56 (6027.46–39543.61)
Operation Performed		
Yes	34 (79.1)	6727.71 (1804.59–10148.33)
No	9 (20.9)	13764.74 (6337.11–17692.33)
Multiple Fractures		
Yes	15 (34.9)	6782.02 (2917.24–17714.29)
No	28 (65.1)	8259.80 (2204.02–13666.47)
Nature of Fracture		
Open fracture	5 (13.5)	2139.69 (383.14–6237.45)
Closed fracture	32 (86.5)	8259.80 (3492.52–13666.47)
Main Body Area Injured		
Upper limb	25 (67.5)	7835.01 (712.81–12535.70)
Lower limb	12 (32.5)	7664.70 (3492.52–16726.90)
Admission Status		
ICU/HD	4 (9.3)	8496.65 (6307.89–70766.27)
General ward	39 (90.7)	7237.61 (2139.69–13764.74)
Discharge Destination		
Home	40 (93.0)	7536.31 (2204.02–15547.03)
Transferred to other hospitals	3 (7.0)	8445.92 (NA)

Table 2
Gender distribution of patients with injuries sustained from various modes of transport.

Year	Author	Transport involved in accident	Sample size (n)	No. of males (%)	No. of females (%)
1979	Zettas et al. ⁸	Motorcycle	260	235 (90.4)	24 (9.6)
1988	Rivara et al. ⁹	Motorcycle	107	91 (85.0)	16 (15.0)
2002	Lateef ¹⁰	Motorcycle	1809	1733 (95.8)	76 (4.2)
2014	Miki et al. ¹¹	Motorcycle	381	324 (85.0)	57 (15.0)
2020	Current study	PMD	41	36 (83.7)	7 (16.3)

Table 3
Healthcare-related costs of patients with injuries sustained from various modes of transport.

Year	Author	Transport involved in accident	Average cost (US\$)
1987	Bried et al. ²³	Motorcycle	16,408
1988	Rivara et al. ⁹	Motorcycle	25,764
2014	Miki et al. ¹¹	Motorcycle	560.73
2017	Gaither et al. ¹⁵	Bicycle	30,664
2020	Current study	PMD	5620

patients requiring surgery were included in the study. The mean cost of surgical admission (inclusive of surgery) was NZ\$14975 for an average length of stay of 4 days. After discharge, each patient averaged 2.65 outpatient visits and at least 50% of patients were still on follow up at time of study completion.

In motorcycle accidents, lower limb injuries predominate. The incidence of lower limb injuries from motorcycles range between 58.3 and 75.5%, as compared to 9.4–33.8% in upper limbs 8, 10–11. Tibia fractures were the most common lower limb injuries. This was in contrast with the current study where upper limb injuries were more common in PMD-related accidents as compared to

lower limb injuries (67.5% of patients vs 32.5% of patients). Another study performed by Cha et al., in 2020 supported our findings, where accidents involving PMDs and electric bicycles resulted in more upper limb than lower limb injuries (25.1% vs 10.4%).²⁵ Despite the difference in the most common injury mechanism and the injury type between motorcycle and PMD related accidents, there was no significant difference in treatment costs.

Most PMD-related accidents arose from self-skidding where riders lost control of the PMDs. Accidents arising from other vehicles, including motorcycles, were more often involved in collisions instead. This study also found that patients who self-skidded had a slightly higher median cost than those who were involved in collisions. It should be noted that each collision is likely to result in multiple victims being injured, and hence the median cost arising as a result of the accident itself could potentially be similar. PMD-related injuries result in significant financial and safety costs. Hence the Singapore government had implemented the AMAtO regulate PMD usage and ensure safety of other users of public paths, including pedestrians and cyclists. Sanctions would be imposed if PMD users defied the code of conduct defined by the AMA. However, there is still no legislation on use of protective gear during PMD use. In this study, less than 20% of patients were

wearing protective gear at time of accident. These patients had a slightly higher median cost payable per patient as compared to those who donned protective gear. However, data on the form of protective gear worn was not available. A study conducted by Shankar et al. found that motorcyclists without helmets spent an average of US\$30365 per patient for hospitalization, which was three times the cost of that of helmeted riders.²⁶ Helmet use has been mandated for motorcyclists but not for PMD users in Singapore. Other forms of protective gear such as limb protection should also be considered, taking into account the high incidences of limb injuries in PMD-related accidents. There is need to raise public awareness on safety measures such as use of protective gear and the risks of PMD accidents due to reckless use. Future studies are needed to analyze the injury pattern and cost associated with use of different forms of protective gear.

Our current study did not take into account the costs of further outpatient follow up appointments required, or the inpatient rehabilitation costs required post-transfer to a step-down institution. Costs of musculoskeletal rehabilitation for injuries sustained from road traffic accidents in developed countries such as Italy can cost up to €11140 (approximately US\$12652).^{27–28} The socio-economic burden of PMD-related injuries in terms of productivity loss, long-term work absence as well as loss of quality of life needs to be studied further.

5. Conclusion

The prevalence of PMD use and related orthopedic injuries during the study period showed significant health and financial costs to both the individual and society. This can be reduced with strict regulations on PMD use, advocating protective gear use, and promoting awareness on safety measures and the consequences of PMD-related accidents. The commonest injury mechanism and injury type for PMD accidents are different from motorcycle accidents.

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