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**Analysis of the Crash Characteristics of Senior Motorcyclists in Serious
Accidents in Straight Lanes**

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ABSTRACT

In Taiwan, motorcycles are a popular mode of transportation. Although motorcycles are a dangerous transportation mode, they still play an important role because they are a convenient means of transportation. Numerous seniors ride motorcycles for their daily activities, especially in rural areas where public transportation is infrequent or nonexistent. There have been numerous serious accidents involving senior motorcyclists occurring in straight lanes, but there are few studies investigating the causalities for this type of accident. This study aims to identify the accident characteristics for senior motorcyclists. This study analyzes crashes involving elderly motorcyclists in Taiwan from 2006 through 2010 to investigate accident characteristics. In total, 22,856 (33.5%) senior motorcyclists were involved in accidents occurring in straight lanes, and 17,809 (77.9%) of these were two-vehicle accidents. We investigate two-vehicle accidents to understand their accident characteristics, and the results show that the four major accident types in straight lanes are the following: the sideswipe accident not resulting from an improper turn, the sideswipe accident resulting from an improper turn, the rear-end accident and the head-on accident. This study identifies six major types of road configurations, and identifies crash characteristics for the different types of roads. Based on the analysis results, we provide a summary of safety concepts for senior motorcyclists to increase their safety awareness and help them avoid traffic accidents.

Keywords: crash characteristics, motorcycle, senior motorcyclists

INTRODUCTION

In Taiwan, motorcycles are a popular mode of transportation, with an average motorcycle ownership of 0.6 motorcycles per person. Because of various factors, including lack of protection, motorcyclists are vulnerable road users. This is especially true for elderly motorcyclists, as shown in Table 1. Compared with motorcyclists aged 18-64 years, senior motorcyclists had more serious injuries as a result of accidents. Between 2006 and 2010, 1.9% of senior motorcyclists involved in crashes died as a result and 93.3% were injured. During the same time period, 0.6% of motorcyclists aged 18-64 years involved in crashes died and 89.0% were injured. In areas of Taiwan where public transportation is not well developed, motorcycles are the major transportation mode for the elderly (Chen, 2010). As expected, among all transportation modes, motorcycles present the most serious safety problems for the elderly in Taiwan as illustrated in Table 2. More than half of the seniors involved in crashes were motorcycle riders. The number of senior motorcycle crash victims increased from 12,031 in 2006 to 17,831 in 2010. On average, 39 senior motorcyclists were involved in crashes every day, and the accident rate for motorcycle riders was much higher than the accident rate for users of other transportation means. It is forecasted that Taiwan will become an aged society as soon as 2017. This projection, combined with the huge popularity of motorcycles makes motorcycle safety for seniors an urgent priority for Taiwan. Numerous serious accidents involving senior motorcyclists occur in straight lanes, but there are few studies investigating the causalities for this type of accident. Most studies have focused on safety issues at intersections (e.g., Clarke et al., 2007; Majdzadeh et al., 2008). This study aims to identify the accident characteristics of crashes involving senior motorcyclists in

straight lanes in order to develop educational safety programs for senior riders.

Table 1 Injury severity for motorcyclists involved in crashes by age group

| Age group | Injury Severity | | | |
|------------|-----------------|--------------------|-------------------|---------|
| | Death | Injury | Non-injury | Total |
| 18-64 | 5,207 (0.6%) | 771,200 (89.0%) | 89,863 (10.4%) | 866,270 |
| 65 or over | 1,341 (1.9%) | 66,873 (93.3%) | 3,463 (4.8%) | 71,677 |

Table 2 Seniors involved in crashes by different transportation means

| Year | Large vehicle driver | Small truck driver | Passenger car driver | Motorcycle rider | Bicycle rider | Pedestrian | Total |
|---------------|----------------------|--------------------|----------------------|-------------------|-------------------|-------------------|---------------------|
| 2006 | 70 (0.3%) | 731 (3.4%) | 2,633 (12.3%) | 12,031 (56.2%) | 2,361 (11.0%) | 3,599 (16.8%) | 21,425 (100.0%) |
| 2007 | 74 (0.3%) | 811 (3.6%) | 2,891 (12.8%) | 12,555 (55.7%) | 2,515 (11.2%) | 3,704 (16.4%) | 22,550 (100.0%) |
| 2008 | 51 (0.2%) | 837 (3.4%) | 3,112 (12.7%) | 13,770 (56.1%) | 2,920 (11.9%) | 3,849 (15.7%) | 24,539 (100.0%) |
| 2009 | 46 (0.2%) | 1,018 (3.7%) | 3,516 (12.8%) | 15,567 (56.9%) | 3,275 (12.0%) | 3,942 (14.4%) | 27,364 (100.0%) |
| 2010 | 76 (0.2%) | 1,208 (3.9%) | 4,265 (13.7%) | 17,831 (57.3%) | 3,554 (11.4%) | 4,193 (13.5%) | 31,127 (100.0%) |
| Total | 317 (0.2%) | 4,605 (3.6%) | 16,417 (12.9%) | 71,754 (56.5%) | 14,625 (11.5%) | 19,287 (15.2%) | 127,005 (100.0%) |
| Daily Average | 0 | 3 | 9 | 39 | 8 | 11 | 70 |

INITIAL ANALYSIS OF ACCIDENTS INVOLVING SENIOR MOTORCYCLISTS IN STRAIGHT LANES

This study analyzes crashes involving elderly motorcyclists in Taiwan from 2006 through 2010 to investigate accident characteristics. In total, 71,754 senior motorcyclists were involved in accidents during this period, and 22,856 (33.5%) of these seniors were involved in accidents occurring in straight lanes. Of these 22,856 senior motorcyclists, 4,168 (18.2%) were involved in single-vehicle accidents (*e.g.*, hitting a tree), 17,809 (77.9%) were involved in two-vehicle accidents (*i.e.*, colliding with one other vehicle), and 879 (3.8%) were involved in accidents involving three or more vehicles.

The solid line in Figure 1 shows the number of senior motorcyclists involved in single-vehicle accidents by time of day, and the dashed line shows the number of senior motorcyclists involved in accidents involving two or more other vehicles. The two lines in Figure 1 match the typical pattern of travel for seniors. Taiwanese seniors typically like to go out in the morning, usually returning home for lunch followed by a nap. Seniors may also go out in the afternoon and return home before dark. Figure 1 shows that most accidents involving senior motorcyclists occurred during morning peak traffic hours (*i.e.*, 8:00–10:00). These data indicate a need to enhance senior motorcyclists’ riding skills and safety awareness in congested traffic conditions.

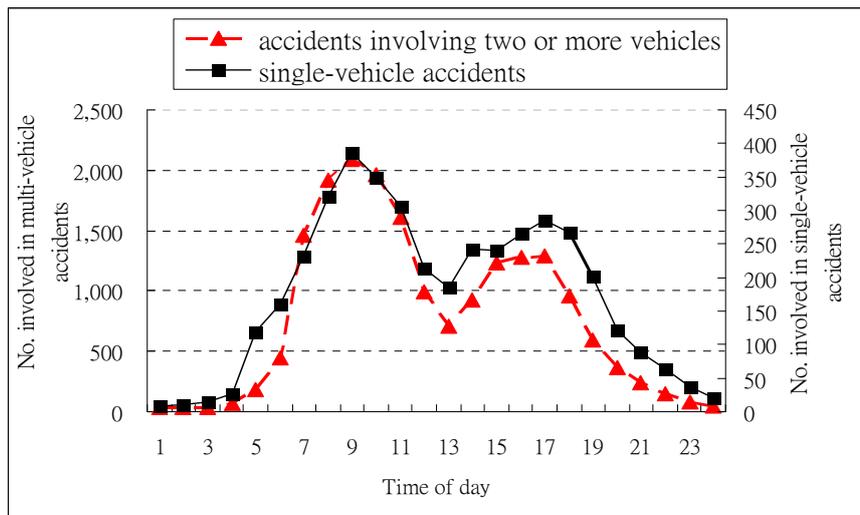


Figure 1 Senior motorcyclists involved in single-vehicle and multiple-vehicle accidents by time of day

Table 3 shows the number of senior motorcyclists involved in crashes by age group. Numerous older senior motorcycle riders were involved in crashes; 2,932 (12.6%) of the senior motorcyclists involved in crashes were aged 80 or over, and of these, the ten oldest motorcyclists were 98 years old. Developing ways to evaluate the physical and mental fitness of seniors to ride motorcycles is a topic that should be thoughtfully investigated in future studies to provide constructive evaluation suggestions. Alternative transportation means should be provided for seniors if they are no longer able to safely ride motorcycles.

Table 3 Senior motorcyclists involved in accidents by age group

| <i>Age group of motorcyclist</i> | <i>Number of motorcyclists</i> | <i>%</i> |
|----------------------------------|--------------------------------|----------|
| 65-69 | 8,840 | 38.7 |
| 70-74 | 6,432 | 28.1 |
| 75-79 | 4,652 | 20.4 |
| 80-98 | 2,932 | 12.8 |
| Total | 22,856 | 100.0 |

Because most of the senior motorcyclists were involved in two-vehicle accidents (78%), this study explored causes for this type of accident. Accidents in which senior motorcyclists were at fault (Table 4) as well as accidents in which they were not at fault were analyzed (Table 5). The major accident causes for senior motorcyclists who were at fault included the following: not paying attention to the traffic ahead, violating traffic signs/markings, failing to yield, violating driving direction (*e.g.*, driving the wrong way on a one-way street), not maintaining a safe lateral distance from other vehicles, making an illegal lane change, not paying attention to other vehicles/people when starting (*i.e.*, senior motorcyclists starting from the roadside entered traffic in an unsafe manner or at an unsafe time), making an illegal left turn, and not carefully crossing the road. The major known accident causes for senior motorcyclists who were not at fault included the following: not paying attention to the traffic ahead, not maintaining a safe lateral distance from other vehicles, not staying in the lane(s) on the right hand side of the road, and violating traffic signs/markings. The top cause was not paying attention to the traffic ahead. The road features and collision types will be discussed in more detail in the next section to better understand how the two-vehicle accidents happened.

Table 4 The causes of accidents in straight lanes for senior motorcyclists who were at fault

| <i>Cause</i> | <i>Number</i> | <i>%</i> |
|--|---------------|----------|
| 1. Not paying attention to traffic ahead | 1,025 | 15.1 |
| 2. Violating traffic sign/markings | 751 | 11.1 |
| 3. Failing to yield | 599 | 8.8 |
| 4. Violating driving direction | 530 | 7.8 |
| 5. Not keeping safe lateral distance from other vehicles | 525 | 7.7 |
| 6. Making illegal lane change | 455 | 6.7 |
| 7. Not paying attention to other vehicles/people when starting | 427 | 6.3 |
| 8. Making illegal left turn | 421 | 6.2 |
| 9. Not keeping safe gap behind vehicle ahead | 383 | 5.6 |
| 10. Not carefully crossing the road | 314 | 4.6 |
| Other causes or missing data | 1,362 | 20.1 |
| Total | 6,792 | 100.0 |

Table 5 The causes of accidents in straight lanes for senior motorcyclists who were NOT at fault

| <i>Cause</i> | <i>Number</i> | <i>%</i> |
|--|---------------|----------|
| 1. Did not find cause | 5,628 | 51.1 |
| 2. Not paying attention to traffic ahead | 2,345 | 21.3 |
| 3. Not keeping safe lateral distance from other vehicles | 986 | 8.9 |
| 4. Other violations | 503 | 4.6 |
| 5. Cause unknown | 466 | 4.2 |
| 6. Not staying in the lane(s) on the right hand side | 228 | 2.1 |
| 7. Violating traffic sign/marking | 143 | 1.3 |
| 8. Making illegal left turn | 95 | 0.9 |
| 9. Drunk driving | 78 | 0.7 |
| 10. Failing to yield | 72 | 0.7 |
| Other causes or missing data | 473 | 4.3 |
| Total | 11,017 | 100.0 |

ANALYSIS OF ACCIDENT COLLISION TYPES IN STRAIGHT LANES

Of the 17,809 older motorcyclists involved in two-vehicle accidents in straight lanes, 9,663 (54%) collided with small vehicles (*i.e.*, passenger cars or small trucks), and 6,626 (37%) collided with other motorcycles. The ratio of collisions with small vehicles to collisions with other motorcycles was about 3 to 2. Of the senior motorcyclists that collided with small vehicles, 1.8% of the senior motorcyclists died, and 97.0% of them were injured. Of the senior motorcyclists that collided with other motorcycles, 0.7% of the senior motorcyclists died, and 89.1% of them were injured. The injury level for senior motorcyclists that collided with small vehicles was more serious than the injury level for those that collided with motorcycles. The accident dataset built by the National Police Agency, Ministry of the Interior included only those accidents resulting in at least one injured person; non-injury accidents were not included in the dataset. Since accidents involving senior motorcyclists colliding with other motorcycles were not included, it appears that more accidents occurred between senior motorcyclists and small vehicles; however, if the non-injury accidents had been included, the number of accidents between senior motorcyclists and other motorcyclists would have been higher than the number of accidents between senior motorcyclists and small vehicles.

As shown in Table 6, the four major accident types in straight lanes were the following: the sideswipe accident not resulting from an improper turn, the sideswipe accident resulting from an improper turn, the rear-end accident and the head-on accident. There was a difference in accident types between motorcycle-small vehicle collisions and motorcycle-motorcycle collisions. The top accident type for senior motorcyclists colliding with small vehicles was the sideswipe-no improper turn (41.4%) followed by the sideswipe-improper turn (23.2%). In accidents between senior motorcyclists and other motorcyclists, however, senior motorcyclists were slightly more

likely to have a sideswipe-improper turn accident (30.0%) than a sideswipe-no improper turn accident (29.4%). The accident type of sideswipe-no improper turn refers to a situation in which both vehicles are traveling in the same direction and collide when the side of one vehicle strikes the side of another. The sideswipe-improper turn accident type refers to a situation in which one vehicle is traveling straight and the other vehicle makes a left turn, U-turn or right turn from the same or opposite direction, going directly across the straight lanes. Figure 2 illustrates motorcycles making improper left turns or U-turns, and colliding with small vehicles or motorcycles in straight lanes.

Table 6 Accident types and vehicle types for other vehicles involved in accidents with senior motorcyclists in straight lanes

| <i>Accident type</i> | <i>Small vehicles</i> | | <i>Other motorcycles</i> | |
|----------------------------|------------------------------------|----------|------------------------------------|----------|
| | <i>No. of senior motorcyclists</i> | <i>%</i> | <i>No. of senior motorcyclists</i> | <i>%</i> |
| Sideswipe-no improper turn | 4,003 | 41.4 | 1,946 | 29.4 |
| Sideswipe-improper turn | 2,237 | 23.2 | 1,990 | 30.0 |
| Rear-end | 866 | 9.0 | 1,245 | 18.8 |
| Head-on | 739 | 7.6 | 902 | 13.6 |
| Others | 1,818 | 18.8 | 543 | 8.2 |
| Total | 9,663 | 100.0 | 6,626 | 100.0 |

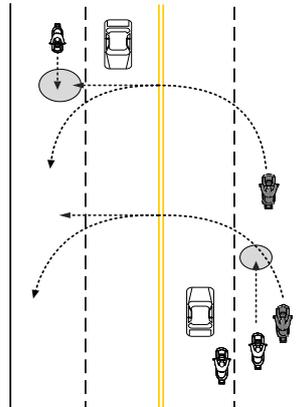


Figure 2 Improper left turns and U-turns by motorcyclists involved in accidents in straight lanes

This study investigates the collision types for different types of straight-lane road configurations; in addition, the types of vehicles involved in accidents with senior motorcyclists are also considered. The different types of central section in the straight-lane road configuration include medians (*e.g.*, central raised curb and New Jersey median barriers), double yellow lines (passing prohibited in both directions) and a single broken yellow line (passing permitted). The types of lanes include fast lanes, mixed traffic lanes (*i.e.*, lane used by both vehicles and motorcycles), and slow lanes (used by motorcycles and bicycles only). The most popular types of road configuration are shown in Tables 7 and 8. For example, the Type 1-Me-F-S road configuration

consists of two directions of traffic divided by a median, and having at least one fast lane, one mixed lane and one slow lane, which is used exclusively by motorcycles and bicycles. There is at least one fast lane in Types 1, 2, 3, 4, 7 and 8. All the configurations include a mixed traffic lane, which is usually wider than the fast lane. Most of the senior motorcyclists had accidents on those 10 types of road configuration. On road configurations other than Types 1-10, the number of senior motorcyclist-small vehicle accidents was 844 (8.7%), and the number of senior motorcyclist-motorcycle accidents was 794 (12.0%). Table 9 shows the most frequent accident types of two-vehicle accidents for senior motorcyclists by road types. The collision characteristics for the different types of road configurations are described as follows:

1. In general, the most frequent type of accident was the sideswipe, except on the Type 10-Ø-Ø-Ø road. The Type 10 road is an undivided road with only one lane for both directions. Predictably, head-on accidents were more frequent on this type of road than on other types of roads.
2. On roads with a median, the most frequent type of accident for senior motorcyclists-small vehicle or senior motorcyclist-motorcycle accidents was the sideswipe-no improper turn. However, there were also numerous sideswipe-improper turn accidents that occurred on the straight-lane roads with a median. This is related to the presence of a break in the median (see Figure 3): drivers or motorcyclists made left turns or U-turns at the break in the median and collided with vehicles approaching in the straight lane(s).
3. If there was striping dividing the two directions of traffic, the most frequent type of senior motorcyclist-small vehicle accident was the sideswipe-no improper turn, and the most frequent type of senior motorcyclist-motorcycle accident was the sideswipe-improper turn. As shown in Tables 10 and 11, in senior motorcyclist-motorcycle accidents, the pre-crash maneuver of 22.2% of the seniors was to make a left or U-turn. This is a considerably higher percentage than that for the senior motorcyclist-small vehicle accidents, in which 9.2% of the seniors made a pre-crash left or U-turn. The left or U-turn issue is clearly a problem for senior motorcyclists and merits future research. Senior motorcyclists need to be urged to make left or U-turns at intersections only instead of making left or U-turns when traveling in straight lanes.
4. Type 6-DY-Ø-Ø roads are narrow. Although vehicle passing is prohibited in both directions in the straight lanes divided by double yellow lines, senior motorcyclists still need to pay attention to the vehicle ahead of them and not violate the driving direction to avoid head-on accidents.
5. As shown in Table 10, another safety issue for senior motorcyclists traveling in straight lanes is colliding with small vehicles that are entering traffic (21.3% of the senior motorcyclists collided with small vehicles that were starting from the roadside). Senior motorcyclists need to pay more attention to vehicles parked on or starting from the roadside.



Figure 3 The break in the median on a Type 1-Me-F-S road

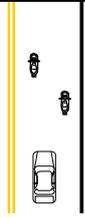
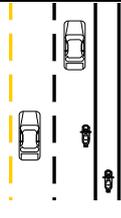
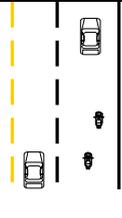
Table 7 Types of straight-lane road configurations (Types 1-5)

| Sketch | Type 1: <i>Me-F-S</i> | Type 2: <i>Me-F-Ø</i> | Type 3: <i>DY-F-S</i> | Type 4: <i>DY-F-Ø</i> | Type 5: <i>DY-Ø-S</i> |
|-----------------|--------------------------|--------------------------|--------------------------|--------------------------|--------------------------|
| | | | | | |
| Center line | Median | Median | Double Yellow | Double yellow | Double yellow |
| Fast lane | Yes | Yes | Yes | Yes | No |
| Mixed flow lane | Yes | Yes | Yes | Yes | Yes |
| Slow lane | Yes | No | Yes | No | Yes |
| Small vehicle* | 807(8.4%) | 443(4.6%) | 1,101(11.4%) | 1,304(13.5%) | 770(8.0%) |
| Motorcycle** | 610(9.2%) | 272(4.1%) | 843(12.7%) | 871(13.1%) | 568(8.6%) |

Note: * Number of senior motorcyclists that collided with small vehicles.

** Number of senior motorcyclists that collided with other motorcycles.

Table 8 Types of straight-lane road configurations (Types 6-10)

| Sketch | Type 6: DY-Ø-Ø | Type 7: SY-F-S | Type 8: SY-F-Ø | Type 9: SY-Ø-Ø | Type 10: Ø-Ø-Ø |
|-----------------|---|---|---|--|---|
| |  |  |  |  |  |
| Center line | Double yellow | Broken yellow | Broken yellow | Broken yellow | Undivided road |
| Fast lane | No | Yes | Yes | No | Only one lane |
| Mixed flow lane | Yes | Yes | Yes | Yes | for two directions |
| Slow lane | No | Yes | No | No | |
| Small vehicle* | 1,151(11.9%) | 492(5.1%) | 828(8.6%) | 814(8.4%) | 1,109(11.5%) |
| Motorcycle** | 632(9.5%) | 357(5.4%) | 528(8.0%) | 536(8.1%) | 615(9.3%) |

Note: * Number of senior motorcyclists that collided with small vehicles.

** Number of senior motorcyclists that collided with other motorcycles.

Table 9 Most frequent accident types of two-vehicle accidents for senior motorcyclists by road types

| Road Type | Involved Vehicle | No. * | Most frequent types of accidents | | |
|-------------------------------|------------------|-----------------------------|----------------------------------|--------------------------------|--------------------------------|
| | | | First (%) | Second (%) | Third (%) |
| 1. Type 1: Me-F-S | Small Veh. | 807 | Sideswipe-no improper turn(44) | Sideswipe-improper turn(20) | Rear-end(12) |
| | Motorcycle | 610 ^{(5)**} | Sideswipe-no improper turn(40) | Rear-end(34) | Sideswipe-improper turn(13) |
| 2. Type 2: Me-F-Ø | Small Veh. | 443 | Sideswipe-no improper turn(46) | Sideswipe-improper turn(17) | Rear-end(12) |
| | Motorcycle | 272 | Sideswipe-no improper turn(42) | Rear-end(34) | Sideswipe-improper turn(13) |
| 3. Type 3: DY-F-S | Small Veh. | 1,101 ⁽⁴⁾ | Sideswipe-no improper turn(42) | Sideswipe-improper turn(31) | Rear-end(9) |
| | Motorcycle | 843 ⁽²⁾ | Sideswipe-improper turn(37) | Sideswipe-no improper turn(28) | Rear-end(16) |
| 4. Type 4: DY-F-Ø | Small Veh. | 1,304 ⁽¹⁾ | Sideswipe-no improper turn(45) | Sideswipe-improper turn(25) | Rear-end(8) |
| | Motorcycle | 871 ⁽¹⁾ | Sideswipe-improper turn(35) | Sideswipe-no improper turn(27) | Rear-end(16) |
| 5. Type 5: DY-Ø-S | Small Veh. | 770 | Sideswipe-no improper turn(42) | Sideswipe-improper turn(27) | Rear-end(9) |
| | Motorcycle | 568 | Sideswipe-improper turn(40) | Sideswipe-no improper turn(26) | Rear-end(15) |
| 6. Type 6: DY-Ø-Ø | Small Veh. | 1,151 ⁽²⁾ | Sideswipe-no improper turn(44) | Sideswipe-improper turn(21) | Rear-end(8) |
| | Motorcycle | 632 ⁽³⁾ | Sideswipe-improper turn(33) | Sideswipe-no improper turn(25) | Head-on(16) |
| 7. Type 7: SY-F-S | Small Veh. | 492 | Sideswipe-no improper turn(43) | Sideswipe-improper turn(23) | Rear-end(10) |
| | Motorcycle | 357 | Sideswipe-improper turn(34) | Sideswipe-no improper turn(31) | Rear-end(21) |
| 8. Type 8: SY-F-Ø | Small Veh. | 828 ⁽⁵⁾ | Sideswipe-no improper turn(42) | Sideswipe-improper turn(22) | Rear-end(10) |
| | Motorcycle | 528 | Sideswipe-improper turn(31) | Sideswipe-no improper turn(30) | Rear-end(18) |
| 9. Type 9: SY-Ø-Ø | Small Veh. | 814 | Sideswipe-no improper turn(39) | Sideswipe-improper turn(23) | Rear-end(9) |
| | Motorcycle | 536 | Sideswipe-improper turn(36) | Sideswipe-no improper turn(27) | Rear-end(18) |
| 10. Type 10: Ø-Ø-Ø | Small Veh. | 1,109 ⁽³⁾ | Sideswipe-no improper turn(29) | Head-on(21) | Sideswipe-improper turn(19) |
| | Motorcycle | 615 ⁽⁴⁾ | Head-on(36) | Sideswipe-improper turn(27) | Sideswipe-no improper turn(18) |

Note: * Number of senior motorcyclists involved in accidents

** Accident type ranking based on total number of accidents

Table 10 Pre-crash maneuvers of senior motorcyclists and small-vehicle drivers involved in accidents

| <i>Senior motorcyclist</i> | <i>Small-vehicle driver</i> | | | | | | <i>Others</i> | <i>Total</i> |
|----------------------------|------------------------------|--------------------|-------------------|--------------------------------|---------------------------------|------------------------------|---------------|-----------------|
| | <i>Starting</i> | <i>Left/U-turn</i> | <i>Right turn</i> | <i>Lane change to the left</i> | <i>Lane change to the right</i> | <i>Go straight</i> | | |
| Starting | 14 (0.1)* | 5 (0.1) | 0 (0.0) | 0 (0.0) | 4 (0.0) | 175 (1.8) | 28 (0.3) | 226 (2.3) |
| Left/U-turn | 15 (0.2) | 20 (0.2) | 8 (0.1) | 3 (0.0) | 3 (0.0) | 889 (9.2) | 11 (0.1) | 949 (9.8) |
| Right turn | 5 (0.1) | 5 (0.1) | 4 (0.0) | 0 (0.0) | 0 (0.0) | 22 (0.2) | 3 (0.0) | 39 (0.4) |
| Lane change to the left | 5 (0.1) | 3 (0.0) | 0 (0.0) | 12 (0.1) | 5 (0.1) | 394 (4.1) | 3 (0.0) | 422 (4.4) |
| Lane change to the right | 5 (0.1) | 1 (0.0) | 2 (0.0) | 2 (0.0) | 3 (0.0) | 53 (0.6) | 1 (0.0) | 67 (0.7) |
| Go straight | 2055 (21.3) | 792 (8.2) | 250 (2.6) | 66 (0.7) | 279 (2.9) | 3517 (36.4) | 771 (8.0) | 7730 (80.0) |
| Others | 22 (0.2) | 5 (0.1) | 5 (0.1) | 2 (0.0) | 5 (0.1) | 171 (1.8) | 20 (0.2) | 230 (2.4) |
| Total | 2121 (22.0) | 831 (8.6) | 269 (2.8) | 85 (0.9) | 299 (3.1) | 5221 (54.0) | 837 (8.7) | 9663 (100.0) |

Note: * Indicates percentage

Table 11 Pre-crash maneuvers of senior motorcyclists and other motorcyclists involved in accidents

| <i>Senior motorcyclist</i> | <i>Other motorcyclists</i> | | | | | | <i>Others</i> | <i>Total</i> |
|----------------------------|----------------------------|--------------------|-------------------|--------------------------------|---------------------------------|------------------------------|---------------|-----------------|
| | <i>Starting</i> | <i>Left/U-turn</i> | <i>Right turn</i> | <i>Lane change to the left</i> | <i>Lane change to the right</i> | <i>Go straight</i> | | |
| Starting | 14 (0.2)* | 5 (0.1) | 1 (0.0) | 0 (0.0) | 0 (0.0) | 499 (7.5) | 4 (0.1) | 523 (7.9) |
| Left/U-turn | 2 (0.0) | 33 (0.5) | 4 (0.1) | 4 (0.1) | 0 (0.0) | 1468 (22.2) | 6 (0.1) | 1517 (22.9) |
| Right turn | 2 (0.0) | 2 (0.0) | 2 (0.0) | 0 (0.0) | 0 (0.0) | 80 (1.2) | 0 (0.0) | 86 (1.3) |
| Lane change to the left | 0 (0.0) | 1 (0.0) | 1 (0.0) | 12 (0.2) | 0 (0.0) | 205 (3.1) | 0 (0.0) | 219 (3.3) |
| Lane change to the right | 0 (0.0) | 0 (0.0) | 0 (0.0) | 0 (0.0) | 2 (0.0) | 39 (0.6) | 0 (0.0) | 41 (0.6) |
| Go straight | 232 (3.5) | 297 (4.5) | 62 (0.9) | 55 (0.8) | 32 (0.5) | 3261 (49.2) | 116 (1.8) | 4055 (61.2) |
| Others | 3 (0.1) | 3 (0.1) | 0 (0.0) | 1 (0.0) | 0 (0.0) | 165 (2.5) | 13 (0.2) | 185 (2.8) |
| Total | 253 (3.8) | 341 (5.2) | 70 (1.1) | 72 (1.1) | 34 (0.5) | 5717 (86.3) | 139 (2.1) | 6626 (100.0) |

Note: * Indicates percentage

Table 12 summarizes the major accident types, their causes and the dangerous pre-crash behaviors of senior motorcyclists. The following safety concepts need to be provided in educational programs for senior motorcyclists to help them avoid sideswipe and head-on accidents:

- Do not make a left turn or U-turn across straight lanes (especially for crossing a double yellow line) to avoid sideswipe-improper turn accidents. Make a left turn or U-turn at an intersection with a traffic signal instead.
- Try to pay attention to other vehicles making a left turn or U-turn across the straight lanes.
- Do not violate the driving direction.
- Try to maintain a safe lateral distance from vehicles in other lanes, and maintain a safe gap behind the vehicle ahead. Since most accidents involving senior motorcyclists occur during the morning peak traffic hours (*i.e.*, 8:00–10:00), seniors need to be more focused and conservative (*e.g.*, avoid making improper left turns) to deal with congested traffic conditions.
- Pay attention to vehicles parked on or starting from the roadside.

Table 12 Summary of major accident causes and dangerous behaviors of senior motorcyclists

| <i>Cause</i> | <i>Major accident types (Senior motorcyclist behavior)</i> |
|--|--|
| 1. Not paying attention to traffic ahead | All of the major accident types (for example, not recognizing vehicles made a left turn or U-turn across the straight lanes) |
| 2. Violating traffic marking | Sideswipe-improper turn in straight lanes with double yellow line (Made a left turn or U-turn across the straight lanes) |
| 3. Failing to yield | Sideswipe-improper turn (Made a left turn or U-turn across the straight lanes and did not yield to vehicles going straight) |
| 4. Violating driving direction | Head-on |
| 5. Not keeping safe lateral distance from other vehicles | Sideswipe-no improper turn |
| 6. Not keeping safe gap behind vehicle ahead | Rear-end |
| 7. Not paying attention to vehicles starting from the roadside | Sideswipe-no improper turn |

CONCLUSIONS AND SUGGESTIONS

1. The number of senior motorcyclist accident victims increased from 12,031 in 2006 to 17,831 in 2010. On average, 39 senior motorcyclists were involved in crashes every day, and the accident rate for motorcycle riders was much higher than the accident rate for users of other transportation means (*e.g.*, 11 pedestrians were involved in crashes every day during the same time period).

2. Among all transportation modes in Taiwan, riding motorcycles presents the most serious safety problems for the elderly. However, although motorcycles are a dangerous transportation mode, they still play an important role because they are a convenient means of transportation. Numerous seniors ride motorcycles for their daily activities. Therefore, it is important to provide senior motorcyclists with important safety concepts to increase their traffic safety awareness and help them avoid traffic accidents.
3. Of the senior motorcyclists involved in crashes, 2,932 (12.6%) were aged 80 or over. Developing ways to evaluate the physical and mental fitness of seniors to ride motorcycles needs to be investigated in future studies. Alternative transportation means need to be provided for seniors if they are no longer able to safely ride motorcycles.
4. Most accidents involving senior motorcyclists occur during the morning peak traffic hours (*i.e.*, 8:00–10:00). Senior motorcyclists' riding skills and safety awareness in congested traffic conditions need to be enhanced.
5. The most frequent type of accident is the sideswipe, except on road configuration Type 10-Ø-Ø-Ø. This road type is an undivided road with only one lane for both directions. Head-on accidents were more frequent on this type of road than on other types of roads.
6. The following safety concepts are important for senior motorcyclists: making a left turn or a U-turn when traveling in straight lanes is an unsafe maneuver for senior motorcyclists, even if they are on a divided road with a break in the median. It is safer to make a left turn or U-turn at an intersection with a traffic signal. Senior motorcyclists also need to pay attention to other vehicles making left turns or U-turns when traveling in straight lanes. In addition, they need to pay attention to vehicles parked on or starting from the roadside.

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