# CHARACTERISTICS OF MOTORCYCLE ACCIDENTS

J.A. NEWMAN, Department of Mechanical
Engineering, University of Ottawa,
OTTAWA, (Canada)

## Introduction

Injuries resulting from motorcycle accidents have been a matter of considerable concern for the past several years. In the early and mid-1960's, studies were conducted (1,2,3)* which, though providing somewhat less than a sound basis upon which to initiate corrective measures, did point up what appeared to be a major traffic problem. However, references to motorcycles being the "most deadly vehicle" on the road, as motorcycling injuries being of "epidemic proportions" reflected perhaps a certain degree of subjectivity in the interpretation of the rather limited statistics available at the time. Nevertheless, they brought sharply into focus the need for a more detailed and comprehensive examination of what in fact is a significant traffic problem.

Recently investigations have begun to study in detail various accident mechanisms and injury patterns. Drysdale et al (4) have conducted a very comprehensive study of injuries to motorcyclists by drawing upon police and hospital records and on questionnaires sent to two thousand motorcyclists. Hight, Siegel et al (5,6) have conducted similar studies (on a smaller scale) in which injury patterns have been related to occupant impact characteristics.

The object of the present paper is to present heretofore unpublished data resulting from an in-depth study of motorcycle accidents in Canada's National Capital Region (Ottawa-Hull, Vanier).

The study, initiated in 1973 by the Traffic Injury Research Foundation of Canada was a follow-up to an earlier study (7) in which special attention was to be paid to the effectiveness of contemporary motorcycle helmets and of the suitability of the Canadian Standards Association Standard D230 by which they were certified (8,9). The object of the present paper is to update the data pertaining to accident mechanisms (10) and to provide baseline information whereby a comparison of vehicle and occupant kinematics and injury patterns can be made with that of Hight, Siegel et al. (5,6).

The methodology utilized in the accident investigations and in data collection has been outlined elsewhere and will not be repeated here (10). It should be pointed out, though, that all accidents reported in the specified region during a specific time interval (June 1-September 30) were investigated; Most of them on-site, immediately after the accident. Accidents involving off-road travel, mini-bikes and mopeds were excluded from the investigation. The investigating unit comprised persons with backgrounds in vehicle accident investigation, mechanical and civil engineering, orthopaedics, sociology and with experience in motorcycle training programmes. All but one

*Numbers in parentheses indicate references at end of paper.

member were motorcyclists, with varying degrees of experience.

## Results

General: To date a total of 271 accidents have been investigated involving 314 persons (271 operators, 43 passengers).

The sex distribution of the accident victims and the age distribution of the motorcycle operators is shown in Table 1 and Table 2 respectively. The distribution of the number of seasons riding experience accumulated by the operator prior to their accident is shown in Table 3. These data confirm that the majority of motorcycle accident victims are male (nearly 90%), less than 23 years of age (approximately 65%) with less than two seasons of riding experience (48%). In this latter regard, it was determined further that of those operators with less than a full seasons experience, nearly 80% of these had been operating a motorcycle for less than one month.

| | Male % | Female % | Total % |
|---|---|---|---|
| Operators | 80.5 | 2.5 | 83 |
| Passengers | 7.0 | 10.0 | 17 |
| Total | 87.5 | 12.5 | 100 |

Table 1. Operator - Passenger Sex Distribution

| Age | <17 | 18-20 | 21-23 | 24-26 | 27-29 | 30 + | Unknown |
|---|---|---|---|---|---|---|---|
| Percent | 7.8 | 43.0 | 14.5 | 17.1 | 5.2 | 7.4 | 5.0 |

Table 2. Operator Age Distribution

| No. Seasons | 0-1 | 1-2 | 2-3 | 3-4 | 4-5 | 5 + | Unknown |
|---|---|---|---|---|---|---|---|
| Percent | 22 | 26 | 8 | 11 | 5 | 16 | 12 |

Table 3. Operator Experience Distribution

Crash Dynamics: In an attempt to describe the actual crash mechanisms, several categories of accidents have been defined. These, along with their relative frequency are delineated in Table 4. The reader may refer to Ref. 10 if further clarification of the various categories is necessary.

The most common (23.5%) type of accident precrash geometry (i.e. category 1, Table 4) is depicted in Figure 1. Beyond a certain point, depending on the speed of the motorcycle and the traffic lane it occupies, a collision is imminent whether the automobile attempts to proceed straight across the intersection or to turn left or right.

| Category | Percent |
|---|---|
| 1. Right Angle Intersection | 23.5 |
| 2. Vehicle Left Turn in Path of Cycle | 19.0 |
| 3. Sideswipe | 16.5 |
| 4. Drift | 8.0 |
| 5. General Loss of Control | 8.0 |
| 6. Loss of Control Due to Foreign Substance on Roadway | 6.5 |
| 7. Rear End Collision - Motorcycle to Vehicle | 5.0 |
| 8. Head-on Collision | 4.0 |
| 9. Striking Pedestrian or Animal | 4.0 |
| 10. Rear End Collision - Vehicle to Motorcycle | 3.5 |
| 11. Miscellaneous | 2.0 |

Table 4. Accident Categories

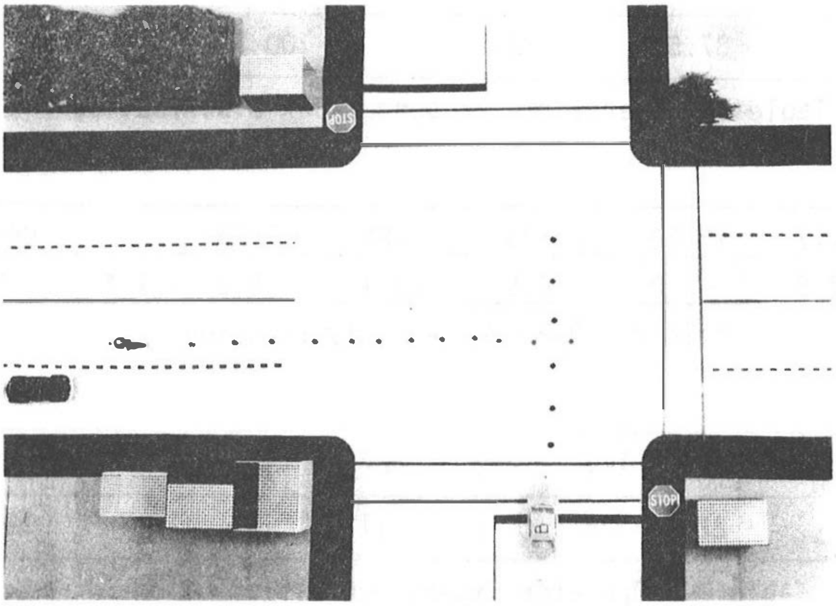


Figure 1. Through Intersection Precrash Geometry (Ref. 10)

The precrash geometry for category 2 (19%), is shown in Figure 2. A collision can only occur if in fact the automobile shown does start to make the left turn indicated.

The third most frequent (16.5%) crash type (category 3) is depicted in Figure 3. This type of accident occurred with approximately equal frequency with the automobile turning left as shown, or turning right with the motorcycle on its right. The fact that this category occupies the third position and not the second is due (it is believed), to the fact that the relative velocity of the two vehicles is considerably lower than in the former cases hence many of this type of accident are avoided as there is sufficient time for either or both vehicle operators to take corrective evasive action.

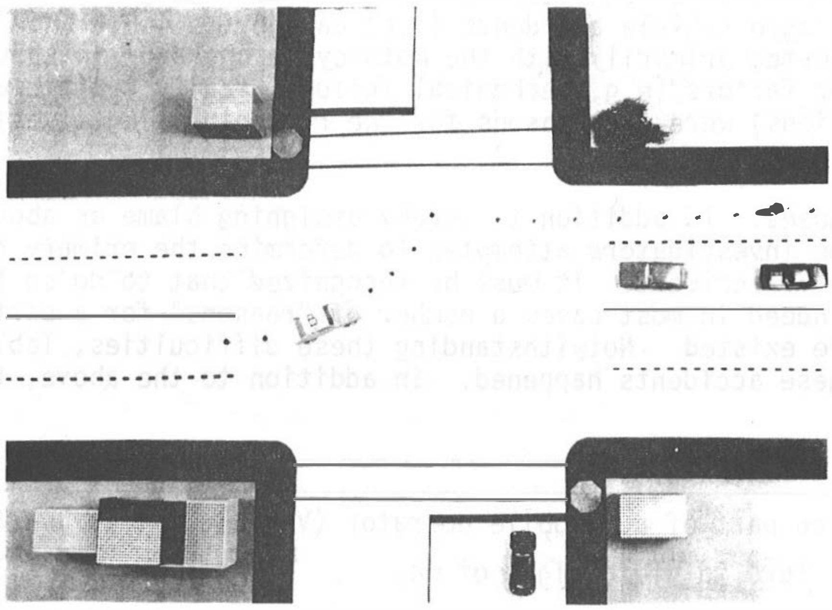

Figure 2. Vehicle B Left Turn Precrash Geometry (Ref. 10)

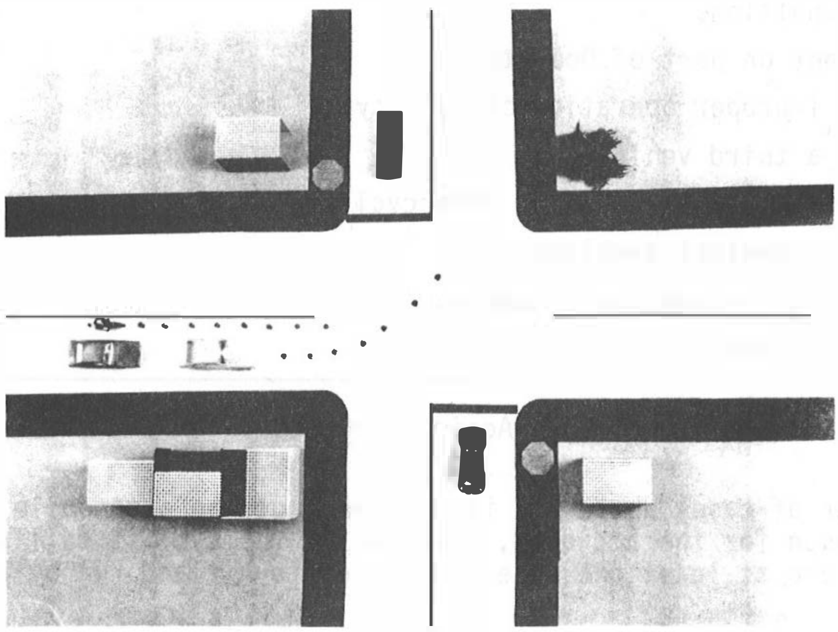

Figure 3. Left Sideswipe Precrash Geometry (Ref. 10)

It is significant to note that the three major categories (59% of all accident types) all involve another vehicle (usually an automobile). The number of accidents for which an automobile was involved constitutes approximately 72% of all accidents. In these cases, the operator of the automobile was judged to be primarily responsible for the accident in 63% of the cases. The operator of the motorcycle was primarily at fault in 20% of these cases and for the remaining 17%, both vehicle operators were judged to be at fault. In the case of single vehicle accidents (i.e. categories 4,5,6 and 7) the responsibility rested primarily with the motorcycle operator in about 50% of the cases. Other factors (e.g. mechanical failure, faulty traffic controls, poor road conditions) were the reasons for the remaining single vehicle accidents.

Accident Causes: In addition to merely assigning blame as above, at each accident site the investigators attempted to determine the primary cause(s) for that particular accident. It must be recognized that to do so is somewhat subjective and indeed in most cases a number of "reasons" for a particular accident may have existed. Notwithstanding these difficulties, Table 5 summarizes "why" these accidents happened. In addition to the above, there were

| Cause | Percent of Cases |
|---|---|
| 1. Inattention on part of automobile operator (Vehicle B) | 52 |
| 2. Vehicle B failure to yield right of way | 50 |
| 3. Motorcyclist's lack of anticipation | 46 |
| 4. Careless driving (including excessive speed)of Vehicle B | 43 |
| 5. Excessive motorcycle speed | 35 |
| 6. Motorcyclist's lack of experience and/or training | 29 |
| 7. Poor road conditions | 21 |
| 8. Poor judgement on part of Operator B | 18 |
| 9. Reckless or improper operation of motorcycle | 10 |
| 10. Presence of a third vehicle | 8 |
| 11. Intoxication or use of drugs by motorcyclist | 7 |
| 12. Motorcycle mechanical problems | 7 |
| 13. Motorcyclist's inattention ("daydreaming") | 6 |
| 14. Motorcycle following traffic too closely | 6 |

Table 5. Accident Causes

a limited number of cases where the inexperience of the automobile driver was the primary reason for the accident, one case of the cyclist falling asleep on his machine and at least one case of deliberate hit and run by an automobile.

The wide variety and multiplicity of reasons for these types of accidents illustrates that simple corrective measures will not be readily available.

Summarizing the seven most frequent causes in Table 5, one would conclude that the majority of motorcycle accidents are due to careless operation of an automobile coupled with the motorcyclist's lack of riding experience and his inability to anticipate or react to a collision hazard. Munroe(11) had summarized the situation rather succinctly (though perhaps in an oversimplified manner) when he indicated that the two greatest threats a motorcyclist faces are "the car driver and his own incompetence". Excessive (though usually legal) speed of both vehicles and poor road conditions are also major contributory factors. The excessive use of alcohol and/or drugs by the motorcycle operator was found to be a factor in only 7.2% of the cases investigated.

Occupant Kinematics: Hight, Siegel, et al. (5,6) have studied data on over 125 injury collisions and have divided the occupant kinematics into three primary classifications; non-ejected, ejected and deflected occupants. Their studies do not, however, take into account non-injury producing accidents nor do they indicate the various proportions of each of the above classifications. In addition, the present study indicates that their classification is somewhat too broad and as such does not give a complete representation of the occupant kinematics. The results of the present study are given in Table 6. The deflection and ejection mechanisms are as described by Hight,

| | Occupant Impact Type | | Percentage of Occupants |
|---|---|---|---|
| (1) | Deflection | | 30 |
| (2) | Ejection | | 27 |
| (3) | Direct Impact | | 18 |
| (4) | Grounding | Forced | 6 |
| | | Intentional | 1 |
| (5) | Ejection followed by direct impact | | 5 |
| (6) | Deflection followed by direct impact | | 4 |
| (7) | Abandonment | | 3 |
| (8) | Combinations of above | | 3 |
| (9) | No impact | | 3 |

Table 6. Occupant Kinematics

Siegel et al. Direct impact refers to the case in which the occupant strikes the impacting object in an essentially normal (i.e. $75^{o}$-$105^{o}$) fashion. Most often, impact was with another vehicle in which the occupants and vehicles came to rest near the impact site. However, occupants are known to have made direct impact with trees, signposts, guard-rails, etc. The classification forced grounding describes the situation whereby the motorcycle is unintentionally laid down at speed due to loss of control brought about by, for example, loose gravel, wet road, oil slick, etc., intentional grounding, on the other hand, refers to deliberate "broadsliding" aimed at averting impact or ameliorating injuries. Abandonment refers to the deliberate act of "bailing out" when collision is imminent. This usually involves jumping up and off the motorcycle in an attempt to avoid collision with the impacting object.

The fact that deflection appears as the most common occupant impact type is that it most frequently occurs in each of the three major accident types (Table 4). Ejection can occur during accident types 1,2,7,8 and possibly 10. It seldom occurs in the third largest category (i.e. sideswipe) and as such appears somewhat less frequently than the deflection mechanism. Direct impact, though the third most frequent impact type (18%), is well behind the former two. The reason for this is that this type of impact will occur only under somewhat special circumstances. It seldom occurs in the case of sideswipe and only occurs in the first two categories if, in the case of collision with a passenger car, impact is near the center of the vehicle or if collision is with a tall vehicle (van or truck). The remaining impact types, though individually not very frequent, do collectively constitute one quarter of all conceivable types of occupant impacts.

Occupant Injuries: A classification of the injuries sustained by the 314 "victims" has shown that less than one half (46%) of the occupants received no or minor injury. One quarter of the occupants sustained injury in the serious to fatal range 8% of which were fatal (i.e. 2% of total). It is perhaps significant to note here that there is probably a significant number of single vehicle accidents which by virtue of so being and resulting in no (or very little) injury were never brought to the attention of the police, hospitals or the investigation team, in spite of what may have been significant property damage. Within the context of the definition of a traffic accident, this fact could substantially reduce the overall injury and fatality rates for motorcycles. The extent to which this is true cannot, of course, be determined, but there is no doubt that more than the 271 accidents investigated (i.e. reported and/or injury producing) occurred during the study period in this particular region.

For those occupants (54%) who did sustain more than minor sprains, abrasions and contusions, the anatomical distribution of these injuries is shown in column 1 of Table 7. The most frequently injured body regions are the upper and lower extremities (23% and 31% respectively). Injuries to the head are the third most frequent (14%).

In Ontario, the mandatory use of helmets has been in effect since 1968 and since 1973 in Quebec. Consequently, the vast majority of the accident victims (over 98%) were wearing a certified motorcycle helmet at the time of their accident. To examine the effect of this on the overall injury distribution, it is instructive to compare the results of Ref. 6 (for the non-helmeted occupants) with that of the present study. The data of Table 7 illustrates how the use of helmets "redistributes" the injuries amongst those who are injured. If one were to compare only columns 1 and 2 of Table 7, one might deduce that though helmets reduce head injury by a factor of more than two (33/14), neck and shoulder injuries increase by nearly threefold. This would lead to the erroneous conclusion that the use of helmets substantially increases the probability of neck (and shoulder) injuries. The same incorrect logic would also lead one to conclude that the use of helmets increases leg and back injuries. In order to make a valid comparison, one must compare the

| Body Region | Injured Helmeted Occupants U.of O. Present Study (1) Percent | Injured Non-Helmeted Occupants USC-TRG Study (6) (2) Percent |
|---|---|---|
| Head, Face, Brain | 14 | 33 |
| Neck, Shoulder | 11 | 4 |
| Thorax | 8 | 11 |
| Upper Extremities | 23 | 14 |
| Abdomen | 2 | 3 |
| Lumbar Region | 9 | 5 |
| Pelvic Girdle | 2 | 3 |
| Lower Extremities | 31 | 27 |

Table 7. Injury Region Distribution

injury distributions for all the accident victims, not just those who were injured. In Ref. 6, all the cases studied were injury accidents. In the present study, only 54% of the occupants received injuries greater than minor. There has in fact been no substantial evidence from this study that helmets cause other injuries.

Further categorization of these injuries into the more frequent occupant impact types has been conducted and is summarized in Table 8 in terms of the most frequently injured areas.

| Impact Type | Injured Region | Percent |
|---|---|---|
| Ejection | Legs | 7.5 |
| | Arms | 5.2 |
| | Head | 3.4 |
| Deflection | Legs | 7.1 |
| | Arms | 3.4 |
| | Head | 2.6 |
| Direct Impact | Legs | 6.0 |
| | Arms | 6.0 |
| | Head | 3.4 |
| Grounding | Arms | 3.4 |
| | Legs | 2.6 |
| | Shoulders | 1.9 |

Table 8. Injury Distribution for Various Impact Types.

In spite of the redistribution of injuries brought about by the use of helmets, the extremities and the head remaining the most frequently injured areas in the three primary impact modes. Only in grounding do head injuries drop to an insignificant level. It is interesting to observe that though direct impact is the least frequent of the three primary impact types, injuries to the arms, legs and head are on the same scale as with the more common impact types. On the other hand, though deflection is the most common impact type, injuries to the arms and head are of lesser significance than for direct impact or ejection. There are, however, fewer leg injuries (7.1%) than in the case of ejection (7.5%) even though the latter occurs less often than the former.

One could take this rationale a step further by considering the contribution of each type of impact to the various injured regions. One would conclude, for example, that injury to the upper extremities is of the highest probability in grounding. (The 7% of the victims who suffered this type of impact accounted for 3.4% of the injuries to this region.) Injuries to the lower extremities due to deflection is only about half as probable. (The 30% of the victims who were deflected accounted for 7.1% of the leg injuries.) Such a breakdown appears to have merit from the standpoint of what evasive action should be taken in an accident and the trends indicated above warrant consideration. Such detailed refinement, however, is not really possible with the limited amount of data on hand. As more cases are collected and studied, the statistical significance of these types of observations may eventually be established.

## Summary and Recommendations

An in-depth analysis of 271 motorcycle accidents in Canada's National Capital Region has been conducted. Victims are generally young, male operators with very limited riding experience. Accidents occur most frequently at intersections and involve another vehicle, the operator of which is most often at fault. For all accident types, improper automobile operation, excessive speed of both vehicles and poor training or experience of the motorcyclist are the primary causes of accidents. The most frequent impact types in descending order are: deflection, ejection, direct impact and grounding. The most common injuries are to the lower and upper extremities. Injuries to the head for this largely helmeted population constitute 14% of all injuries. Based upon this study, the motorcycle accident injury situation can best be improved by the introduction of:

(a) More and more effective motorcycle training programmes.
(b) Better traffic control especially at intersections.
(c) Increased visibility of the cyclist and an improved awareness by automobile operators of the presence of motorcycles on public roads.
(d) Improved arm and leg protection.
(e) More effective helmets.

## Acknowledgement

The study was made possible through the support of the Traffic Injury Research Foundation of Canada, the Federal Department of National Health and Welfare and the Federal Ministry of Transport. To these organizations, the author expresses his sincere gratitude.

The writer would like also to acknowledge with thanks the important contributions made by B.W. Gallup, R. Williams, G. Webster and F. Meunier, the excellent cooperation of the City of Ottawa Police Department and that of the Gloucester Police Department, Nepean Police Department and the City of Vanier Police Department. In addition, the writer would like to thank the emergency staff at each of the Civic, General and Riverside hospitals for their assistance and cooperation.

## References

1. C. Drye, "The Motorcycle: The Etiological Agent of an Epidemic of Trauma". The Journal of Trauma, Volume 5, No. 6, 1965.

2. R.C. Dillihunt, G.L. Maltby, E.H. Drake, "The Increasing Problem of Motorcycle Accidents". Journal of the American Medical Association, Volume 196, June 20, 1966.

3. J. O'Mara, "Motorcycle Accidents -- An Epidemic". Highway Research Record No. 188, Traffic Accident Research, 10 Reports (1967).

4. W.F. Drysdale, J.F. Kraus, C.E. Franti and R.S. Riggins, "Injury Patterns in Motorcycle Collisions", report to the Insurance Institute for Highway Safety, Washington, D.C., March 1974.

5. P.V. Hight, A.W. Siegel and A.M. Nahum, "Injury Mechanics in Motorcycle Accidents", proceedings of the 17th Annual Meeting of the American Association for Automotive Medicine, 1973.

6. A.W. Siegel, P.V. Hight, A.M. Nahum and D.B. Kent-Loop, "Motorcycle Kinematics and Injury Patterns", proceedings of the 19th Annual Meeting of the American Association for Automotive Medicine, pp. 399-408, 1975.

7. E. O'F. Campbell, M.E. MacBeth and S.W. Ryan, "Motorcycle Accidents, Ottawa Area-1967". Report of the Traffic Injury Research Foundation of Canada, Ottawa, Canada. 1968.

8. J.A. Newman, "Motorcycle Helmet Study--The Helmet Standard Dilemma", proceedings of the 10th Annual Meeting of the Traffic Injury Research Foundation of Canada, Ottawa, June 1973.

9. J.A. Newman, "The Protective Value of Contemporary Motorcycle Helmets", presented at the Scientific Conference on Traffic Safety sponsored by the National Department of Health & Welfare, The Traffic Injury Research Foundation of Canada and the Federal Ministry of Transport, May 13-14, 1974, Ottawa, Canada.

10. J.A. Newman and G.D. Webster, "The Mechanics of Motorcycle Accidents", proceedings of the 18th Annual Meeting of the American Association for Automotive Medicine, pp. 265-302, 1974.

11. S. Munroe, "The Development of a National Motorcycle Training Programme", proceedings of the 18th Annual Meeting of the American Association for Automotive Medicine, pp. 303-313, 1974.