THE PROBLEM OF LEG INJURIES IN MOTORCYCLE RIDERS.

A literature survey, a descriptive study of the outcome of motorcycle riders leg injuries supplemented by some results from an accident study.

By:

Erik L. Nordentoft, M.D.,Ph.D., Claus Falck Larsen, Ph.D. and Inge Behrensdorff.

From:

Accident Analysis Group, Institute of Health Economics and Preventive Medicine, Odense University and Danish Council for Road Safety Research.

Introduction

Severe injuries to the legs sustained by motorcyclists are well known among traumatologists. These injuries often lead to long standing or permanent incapacitation. Abrations and superficial injuries can be prevented by protective clothing and boots. Crushing injuries due to the leg being compressed between the motorcycle and a solid obstacle however, need more solid devices if they are to be prevented. To eluci-date the state of affairs of crash protection of motorcyclists legs, and to describe the nature and size of the problem, the following studies have been carried out:

A. A comprehensiv study of the literature on the protective effects of motorcycle crash bars.

B. A study of the frequency, nature and outcome of significant injuries to motorcyclist's legs.

C. A study of the use of crash bars and the influence of these items on the injury patterns in an accident population.

A. COMPREHENSIVE LITERATURE STUDY

A systematic search for relevant literatur was performed through the data bases of IRD, MEDLARS and SAE. The selected papers are refered in chronological order.

1) Motorcycle crash tests

BOTHWELL (1974) reported the results of 7 series of MC–collision tests with a dummy. In severel of the tests the crash bar was deflected by the dummy's leg, and it was concluded, that "conventional crash bars should not be fitted as they are a distinct leg fracture hazard. In motorcar impacts the leg would usually be better off hitting the side of the car than a small diameter tube. No tubular crash bar can be envisaged which would be free of this hazard. Leg protection for motorcyclists needs to be developed without any naked crash bars".

2) UCSD Collision study

HIGHT ET AL (1976) described a study of 127 injured MC–occupants whereof 44 were classified as "deflection cases", that is chrushed against cars. 16 % were fatal, 68 % severe. 93 % of the deflected cases had leg injuries, whereof 70 % severe. The authors recommended a low frame construction and a crash bar behind the passenger seat.

3) Characteristics of motorcycle accidents

NEWMAN (1976) from the Department of Mechanical Engineering, University of Ottawa, Canada published a study on 271 MC–accidents. The study comprised both injured and non–injured riders. Leg injuries were classified as deflection type injuries in 7,1 % and as direct impact injuries in 6,0 % of the cases. An improved protection of arms and legs were recommended but not specified.

4) Accident study and dummy crash tests

KATSUMORI TANEDA (1976) Japan Automobil Research Institute published a large accident study based on accident statistics and experimental studies. The accident study was based on 130.725 two-wheeler accidents. Of these 22.705 were motor-cycles above 250 ccm. 47 % of all collisions were transversal or diagonal. 47 % of the serious injuries were localized to the legs. In the experimental study motorcycles with and without protective devices and equipped with human dummies were brought into collision with passenger cars. Based on these experiments the author concluded that leg protection was possible at collision speeds up to 30–40 km/h. At higher collision speeds injuries to other body regions were dominating. Side protection devices was an effective measure in overturn acidents and in preventing getting run over by the collision vehicle.

5) Motorcycle safety symposium

The conclusions from this symposium, held by the Australian Road Research Board was published by CHAPMANN (1976). It was concluded that:
"The whole design, strength of and fixings of crash bars appear to be deficient. They can be regarded as totally ineffective except perhaps in very mild slides where their role is somewhat beneficial. For effective leg protection crashbars should:
- be strong enough to withstand side impact at 50 km/h by a motor vehicle;
- have attachment to the motorcycle frame which prevent the bars being pushed or bend out of position with respect to the motorcycle frame in side- or angle impact at 50 km/h.
- Have a contour which is a) widest at the upper end, b) has the upper corner well above the center of gravity of the motorcycle/rider system, c) provides rapid decelleration of the motorcycle if it falls and slides on the crash bars, and
- have energy absorbing, impact-attenuating padding to minimize leg injury and torso pitching when the rider or passenger moves foreward or rearward off the motorcycle".

Air bags were tested in frontal collisions, where they were effective. Their effectiveness in side- or rear end collisions could not be evaluated.

6) Development of side impact protection for an EMS (referred from abstract)

BARTOL AND LIVERS (1976) recommended:
"Integral side protection structure capable of protecting the rider's legs from direct as well as oblique side impacts. The structure was a welded double—loop frame constructed of seamless aisi 413 ø tubing".

7) Motorcycle accident cause factors and indentification of countermeasures.

HURT (1979) from University of Southern California reported an on—spot analysis of 900 MC—accidents and a study of 3.600 police reports on MC—accidents. The injuries to the legs were compared with regard to use of crash bars. Riders with crash bars suatained fewer ankle , but not fewer injuries to other parts of the leg than riders without crash bars. The bars were of very different construction and solidity. Both positive effects and deficiencis were found by light as well as by solid bars. Consequently it was found that no advantage was obvious from use of crash bars which help some, but also hurt some, and the over—all effect was no advantage. Large, heavy motorcycles with broad motors yield good leg protection.

8) A survey of motorcycle accidents

WATSON (1973) AND WHITAKER (1976,1980) from TRLL, England have reported an analysis of a total of 425 MC—accidents with 450 injured persons. 1/4 of the injuries were caused by the leg being crushed between the MC and another obstacle. 33 motorcycles were fitted with crash bars and these cases neither the severity nor the frequency of injuries were different from other cases. In the latest paper it was stated that well designed crash bars should serve two purposes: "firstly, they must prevent crushing of the leg in the initial impact, and secondly, they must prevent legs from hitting hard objects near the motordcycle later in the crash. Present crash bars do not appear to fulfill this second function". Experimental research results from the TRRL do not appear to have been published yet.

9) Protective devices for motorcycles

1981—82, according to HÄGGKVIST The National Swedish Road and Traffic Research Institute is developing a protective device which is supposed to fit all motorcyclists independent of hight.

It has leg guards that fold backwards with the driver's lower part af the leg when struck, and attachments that break at certain stresses. Energy absorbing materials are used in the construction.

B. CLINICAL STUDY OF THE NATURE AND OUTCOME OF MC-RIDER'S LEG INJURIES

Material

Over a 3-year period the accident registration at the Odense University Hospital covering a population of 230.000 inhabitants identified 42 cases of leg injuries in motorcycle riders. All 42 cases met the following criteria: admittance to hospital stay with leg injury as the most severe injury sustained. This number corresponds to 10% of all MC-rider casualties seen in the emergency room during the same period of time. In all cases the leg lesion was the only lesion causing extensive problems, except in two cases, - one with a severe lesion in the groin, and one where there were severe lesions in both wrist regions. The case records were examined by a specialist in ortopeadic surgery for selecting the most serious injury and for predicting the length of incapacitation and the degree of permanent disablement. The length of incapacitation was in most cases verified by returning to work or reaching a permanent state of condition. In a few cases the duration of incapacitation is estimated. The degree of permanent incapacitation is estimated on the basis of standard tables from the National Health Authorities.

Results

In the 3-year period from October 9, 1979 to October 8, 1982 42 patients were admitted to hospital stay because of significant leg injuries (7 female, 35 male).

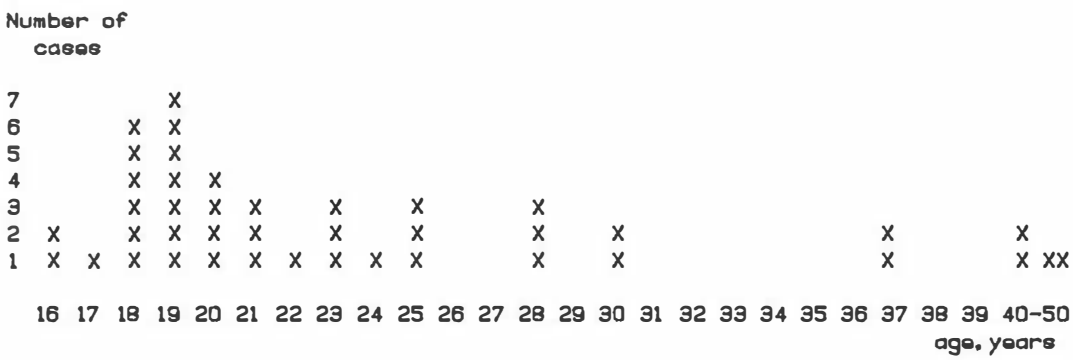
Table 1: The incidence of hospital admittance and severe leg injuries.

	1979	1980	1981	1982
Number of injured motorcyclists seen in the casualty room	103	127	133	117
Hereof admitted to hospital stay because of severe leg injuries	14	9	16	14

30 of the injured were drivers, and 12 were passengers.

Figure 1:

Distribution of age in motorcyclists with severe leg injuries (median age 21 years).



The median age was 21 years. 3 persons were under the minimum legal age (18 years), – all of these were passengers.

Counterparts and accident circumstances

In 25 cases the counterparts were motorized vehicles (here-of 3 lorries). Sixteen cases may biomechanically be classified as single accidents (2 of the 16 collided with road obstacles, 2 with weak counterparts, the remaining 12 presumably were sliding accidents). In one case the counterpart was unknown. In a few cases it was stated that the leg had been crushed, but otherwise the records contain no anamnestic information on the trauma mechanism.

Location and nature of injuries

The location of the most severe injury is shown in table 2.

Table 2: Location of most severe lesion

Thigh	Knee	Lower leg	Foot
10	6	16	10

All thigh lesions and almost all lower leg lesions comprised fractures of the long bones. The knee lesions varied from fracture of patella to severe ligamentous injuries. In most foot injuries there were severe soft tissue damage. Most lower leg lesions were open tibial fractures with extensive soft tissue damage. The femoral fractures varied from spiral fractures as seen by indirect trauma to open transverse fractures and some cases with extensive bone destruction and injury to nerves and vessels.

Table 3 shows the distribution of the duration of incapacitation according to region of leg injured.

Table 3: Mean duration of incapacitation and prevalence of permanent disablement according to region of leg injured.

	REGION INJURED			
	Thigh	Knee	Lower leg	Foot
Median duration of incapacitations (months)	6	4	9	2
Prevalence of permanent disablement	20%	33%	44%	40%

There is a slight tendency to higher prevalence of permanent disablement in more distally lozalized injuries.

Permanent disablement

In 15 cases permanent disablement was stated or estimated on the basis of the degree of the injuries. Disablement was judged solely on the physical handicap on the legs not regarding concomitant injuries to other organs, social or occupational factors. The findings are given in Table 3 and in Figure 3. A little more than 1/3 of the leg injuries leading to hospital admittance in motorcycle riders were thus estimated as leading to some degree of permanent disablement ranging from 5 to 50%.

On the basis of the character of the injuries they could, with a high degree of certainty, be classified as crush injuries in about half of all thigh and knee cases, and in almost all cases of injuries to lower leg and foot. There were very few cases of tangential character.

Length of stay in hospital

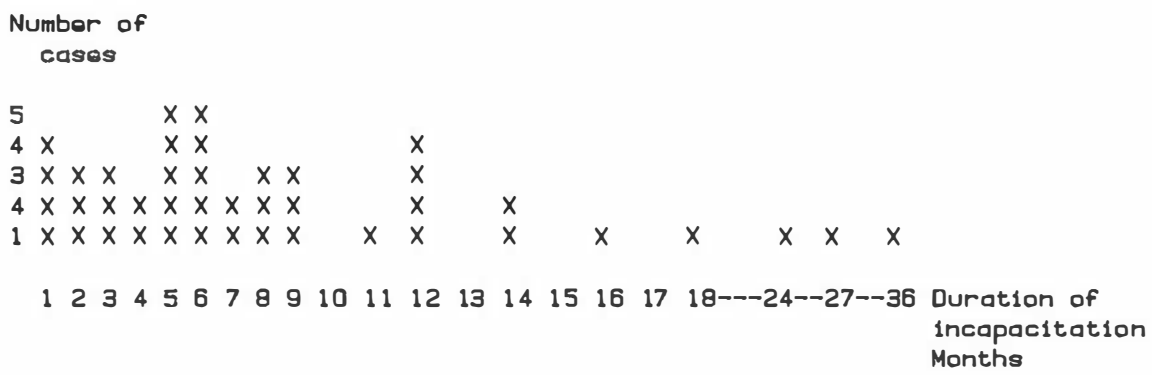
The length of stay after primary admittance to hospital varied from a few days to more than 5 months, — mean stay 38 days. The mean stay for all patients in the traumatological department is 7,2 days, — so in spite of young age population, the MC—injured has a mean stay 5 times as long as the general mean stay for patients in this department.

Duration of incapacitation

The duration of incapacitation is destributed as shown in Figure 2.

Figure 2:

Distribution of duration of incapacitation = period from the time of accident until restitution of occupational ability or until a permanent condition is reached (demonstrated in the first case. - judged by a specialist in the latter case).



The median duration of incapacitation was 7 months.

Figure 3: Distribution of percentage of disablement in 15 permanently disabled.

C. THE ACCIDENT STUDY

In the period following the study period of part II, namely August 1st 1982 to Juli 31, 1983 125 motorcycle riders and passengers were seen in the emergency room, Odense University Hospital. There were 6 fatalities. A questionnaire was send to the remaining 119 survivors, of whom 109 (91,6%) answered questions concerning the accident, the rider and the motorcycle. The 125 patients altogether sustained a total of 256 injuries. Of these injuries 58,2% were minor (AIS 1), 25,4% moderate (AIS 2) and 16,4% severe, serious or critical (AIS > 3). Among the 125 accident victims a total of 91 had leg injuries with a percentage AIS distribution as illustrated in

Table 4: Percentage AIS distribution of leg injuries in 91 motorcycle accident victims.

AIS 1:	64,8%
AIS 2:	15,4%
AIS 3:	18,7%
AIS 4:	1,1%
AIS>5:	0 %

Altogether 62 fractures were registered corresponding to 40% of all injuries. Twentythree of these fractures were localized to the legs. Of these 5 were femoral fractures , 10 fractures of lower leg and 5 fractures localized to the ankle and foot.
The composition of the accident involved motorcycles according to motor size is shown in Table 5.

Table 5: Percentage distribution of accident involved motorcycles according to cylinder volume.

0-410	411-550	551-650	651-750	>750	unknown
39%	13%	7%	22%	15%	4%

Crash bars were fitted to 24 motorcycles. AIS injury rating of the leg injuries related to crash bar is illustrated in Table 6. which only comprise the drivers.

Table 6: AIS distribution of leg injuries in relation to crash bar fitted/not fitted

	AIS 1	AIS 2	AIS 3	Number of patients
Crash bar fitted	11	1	1	24
Crash bar not fitted	31	7	10	62

Among those injured on motorcycles fitted with crash bars only one had a fracture located on the distal part of the femur. In contrast all other fractures mentioned above, located to the lower limb, were sustained by motorcycle riders analysis we have not made distinction between so-called engine case savers and other kinds of crash bars. Table 6 demonstrates a higher rate of more severe leg injuries sustained by riders on motorcycles without crash bars compared to riders on motorcycles fitted with crash bars.However it might well be that crash bars more often were mounted on heavy motorcycles with broad motors. A transverse measure of the motors on the motorcycles involved, were not directly available. The material of accident involved motorcycles were instead broken down into two groups according to cylinder volume below and above 750 ccm, both in the crash bar group and in the group without crash bars. This break down showed an overrepresentation of large motorcycles of or above 750 ccm among those fitted with crash bars. (Table 7).

Table 7:

	Size of motorcycle	
	< 750 ccm	>750 ccm
Crash bars fitted	39%	64%
Crash bars not fitted	69%	31%

Discussion

Severe leg injuries sustained by motorcycle riders has been recognized as a major health problem for years. Life threatening injuries in motorcycle accidents are mostly localized to the brain, the abdomen and the thorax. Tragic permanent disablement often stems from severe brain injury, spinal injury or injury to the brachial plexus. The possibility for effective protection of the brain, head and face by crash helmets is well established although further perfection in construction of the helmets should be possible. Skin and hand lesions can be prevented effectively by protective clothing, while protective measures against lesions to the belly and the spinal cord seem difficult to construct and implement.

The need for effective leg protection for motorcyclists has been recognized in most countries, and a long row of accident studies and laboratory tests have been carried out. It is unanimously stated that the most severe leg lesions derive from the legs being crushed between the motorcycle and some rigid obstacle. However, surprisingly little is known about the exact character of these obstacles, whether the motorcyclists drive into the side of a car, is hit by the front of the car or thrown away hitting corners with his legs. Much information from actual accident reconstruction still seems to be lacking.

Laboratory studies, in most cases, lead to optimistic conclusions as to the possibility of yielding considerably better protection to motorcyclists, – not by screwed on crash bars but by integral frame constructions. The specific geometry and mechanical features of such constructions, which give optimal protection to both driver and passenger in most collision situations however, has not been agreed upon yet. Standardization work on these items seems a long way off and the motorcycle producers do not seem to consider the secondary safety of their products. As long as motorcycles are accepted as a mean transportation in every day traffic, such safety considerations must be intencified. The present study confirms the high rate of severe leg injuries seen in motorcycle riders. Besides, it descripes the outcome of such injuries in more detail, demonstrating the length of stay in hospital, the distribution of duration of incapacitation and the rate and degree of permanent disablement.

It is obvious from this analysis that leg injuries sustained in motorcycle accidents is a heavy load on hospital services and on the surviving victims all the time that the length of incapacitation was 7 months and permanent disablement was found in about 1/3 of all cases.
Contrary to most other studies our accident study revealed a distinct underrepresentation of severe leg injuries in riders of motorcycles which had been fitted with crash bars. This finding might be explained by a higher percentage of large motorcycles with broad motors which also in earlier studies have proved to give good leg protection.
Clinical evidence of the problem is overwhelming. laboratory test results are promising, but in depth accident studies as a guide for laboratory work is still insufficient and the use of laboratory results seem negligible.

BARTOL, JA, LIVERS, GD. Development of side impact protection for an ESM. AMF INC., 495 south fairview Avenue, 93017 Goleta, California, USA, 1976. (IRRD nr. 217551).

BOTHWELL, PW. Motorcycle crash tests. A report on experimental motorcycle crash testing and safety design parameters for the motorcycle. JIM CLARK FOUNDATION, England 1974, s. 1–103. (IRRD nr. 213003)

CHAPMANN, CC, Dip Mech Eng, Commonwealth Department of transport. Motorcycles and Safety. Symposium. Australian Road Research Board, Melbourne juni 1976, s. 164–179. (IRRD nr. 250506)

HIGHT, PV, SIEGEL, EW, NAHUM, AN. Injury mechanisms and motorcycle design. University of California, San Diego, USA, 1973. INTERNATIONAL RESEARCH COMMITTEE ON THE BIOKINETICS OF IMPACTS. Proceedings of the meeting on biomechanics of injury to pedestrians, cyclists and motorcyclists, Amsterdam, september 1976, S. 65–79.

HURT, HUGH H, Jr. Status report of accident investigation data "motorcycle accidents cause factors and identification of countermeasures". University of Southern California, Traffic Safety Center. Motorcycle accident research, University Park, Los Angeles. U.S. DEPARTMENT OF TRANSPORTATION, National Highway Traffic Safety Administration, Washington, D.C. 20590, 1979. s. 84–90.

HÄGGKVIST, B. Säkerhetsanordning för motorcykel. B. Häggkvist, Sieverts Väg 7, S–13200, Saltsjö–Boo. STYRELSEN FÖR TEKNISK UTVECKLING, Box 43200, S–10072 Stockholm, 1982. (IRRD nr. 609249)

Taneda, K.: Experimental Investigation of Motorcycle Safety. IRCOBI, Amsterdam 1976. p. 270–282.

NEWMAN, JA. Characteristics of motorcycle accidents. Department of mechanical engineering, University of Ottawa, Canada. INTERNATIONAL RESEARCH COMMITTEE ON THE BIOKINETICS OF IMPACTS. Proceedings of the meeting on biomechanics of injury to pedestrians, cyclists and motorcyclists, Amsterdam 1976, s. 250–260. (IRRD nr. 224842).

WHITAKER, J. A survey of motorcycle accidents. Transport and Road Research Laboratory, TRRL Laboratory Report 913. Berkshire 1980. (IRRD nr. 248513)