Traffic accident victims and polytrauma patients: injury patterns, outcome and their influencing factors

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Injury pattern, injury severity, and mortality in 33,495 hospital-admitted victims of motorized two-wheeled vehicle crashes in The Netherlands.

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ABSTRACT

Background

Road traffic accidents involving motorized two-wheeled vehicle (MTV) riders often result in severe morbidity and mortality. This nationwide study aims to describe the influence of the type of motorized two-wheeled vehicle on the patient injury severity and mortality upon hospitalization, after MTV accidents in the Netherlands.

Methods

Data from the Institute for Road Safety Research and the Hospital Trauma Databases were analysed. All MTV crash victims admitted to Dutch hospitals from 1993 to 2008 were included. Logistic regression analysis was performed on sex, age, type of MTV, Injury Severity Score and Abbreviated Injury Scale to calculate the relative risks of severe trauma and mortality for motor and light-moped riders according to the Mantel and Haenszel procedure (RRmh).

Results

Among 33,495 MTV crash victims, 10,607 were motorcyclists, 19,708 moped riders and 3,180 light-moped riders. In the light-moped rider group head injury, especially severe head injury was most common in light-moped riders and the prevalence of severe trauma (17.1%) and mortality (4.2%) were highest, compared to motorcyclists and moped riders. In elderly crash victims (> 55 years) the risk to sustain severe trauma was almost twofold higher in light-moped riders compared to moped riders (RRmh 1.79). Young motorcyclists (< 25 years) had the highest chances of dying (RRmh 1.64).

Conclusions

Hospitalized light-moped riders show more severe head injuries, severe trauma, and higher mortality than moped riders and motorcyclists. Young motorcyclists and elderly light-moped riders are most vulnerable, with the highest chances of severe trauma and mortality. Continuing improvement of MTV safety is urgent.

INTRODUCTION

Road traffic accidents involving motorized two-wheeled vehicle (MTV) riders often result in severe morbidity and mortality. Nevertheless, due to increasing congestion on Dutch roads, the MTV is becoming an efficient and increasingly important method of transportation. Compared to other motorized road users (such as cars and trucks), MTV riders are at greater risk of sustaining severe multiple injuries and death after road traffic accidents, because of their vulnerability and relative high driving speed.[1-4] In the '70s of the previous century helmet laws for motorcyclists and moped riders were introduced in the Netherlands. Since then, virtually 100% of motorcyclists use motorcycle helmets. The percentage of moped riders not wearing a helmet at all, or not wearing it correctly has been increasing over the past 10 years.[5] Light-moped riders are not obliged to wear a helmet, which makes this vehicle especially popular amongst young people and the elderly in the Netherlands. In 1993 295,000 persons owned at least one motorcycle and 461,000 persons at least one moped or light-moped. The number of motorcycle owners increased to 431,000 in 2008, and the number of mopeds and light-moped owners increased to 482,000. Light-mopeds and mopeds have an engine cylinder capacity of 50cc and a permitted maximum speed of respectively 25 km/h and 45 km/h. Motorcycles have an engine capacity exceeding 50cc and a permitted maximum speed of 120 km/h. Between 1993 and 2008 a total of 37,779 motorcycle-, 115,054 moped-, and 20,429 light-moped accidents were registered in the Netherland.[6] These numbers concern both hospitalized and none hospitalized crash victims.

The three categories of MTVs in the Netherlands offer the possibility to compare the effects of different types of MTV and their specific driver groups, on injury severity and mortality in hospital-admitted MTV crash victims. Although previous studies described injury severity and mortality related to moped and motorcycle accidents only, none described this relationship in three different types of MTV. [7-10]

This nationwide study aims to analyse injury patterns, -severity and mortality in hospital-admitted MTV crash victims, per MTV group. Additionally, the association between severe trauma, mortality and MTV rider group will be determined according to ascending age categories.

METHODS

Study design

The nationwide Hospital In-patient Registration (LMR) and the Database Registered Crashes in the Netherlands (BRON) were combined and matched by the SWOV Institute For Road Safety Research to create a nationwide traffic accident database containing specific medical data. The SWOV is an independent institute that aims to improve road safety by using knowledge from scientific research. The linked databases, encompassing the most complete and largest collection of traffic accidents assembled in the Netherlands, enabled an analysis of all MTV crash victims, admitted to hospitals from 1993 to 2008. Victims who only visited the emergency department without being admitted, as well as victims who deceased at the scene of the accident or on arrival at the hospital, were not included. No detailed data on helmet use were available.

Definitions & Methods

MTV groups were defined as light-mopeds, mopeds and motorcycles (permitted maximum speeds of respectively 25 km/h, 45 km/h and 120 km/h). MTV accidents were identified using the International Statistical Classification of Diseases and Related Health Problems (ICD-9 Classification). The analysed data included age, sex, type of MTV, Abbreviated Injury Scale update 1998 (AIS)[11], Injury Severity Score (ISS)[12], severe trauma (ISS ≥16), injury severity distribution (AIS > 2 i.e. severe injury) injury pattern description according to AIS anatomical region (Head, Face, Neck, Thorax, Abdomen, Spine, Upper extremities, Lower Extremities, External), and mortality.

Overall changes in severe trauma over time and numbers of hospital admittances during the analysed period were described per MTV group. The anatomic distribution of injury and severe injury (AIS>2) was analysed using the injury description according to AIS per MTV group.

A subgroup analysis was performed on patients with severe head injury (AIS Head > 2) to quantify the expected mortality due to severe head injury. Continuous variables were dichotomized using clinically relevant cut-off points: age (<25yrs, 25-55yrs, >55yrs) and ISS (<16 vs. ≥16). Relative Risks (RR) and corresponding 95% confidence intervals (95% CI) were calculated for severe trauma (ISS ≥16) and mortality per MTV group with moped riders used as the reference category. All risk ratios are adjusted for sex and age category according to the Mantel Haenszel procedure (RRmh).[13]

RESULTS

A total of 33,495 MTV crash victims were admitted to the hospital between January 1st, 1993, and December 31st, 2008. Table 1 shows the demographics of the crash victims. There were 10,607 motorcyclists, 19,708 moped riders and 3,180 light-moped riders. The median age was 24 years (IQR = 21) and 6,516 (19.5%) victims were female. The median age per MTV group was respectively 33 years (IQR =21), 18 (IQR=13) and 30 years (IQR=40). In total, 4,253 (12.7%) crash victims had severe trauma (ISS ≥16), and 816 (2.4%) victims died in the hospital after being admitted.

Table 1. Comparisons of demographics by three groups of motorized two-wheeled vehicle crash victims.

	Total Patients	Motorcyclists	Moped Riders	Light-Moped Riders
	N=33,495 (%)	N=10,607 (%)	N=19,708 (%)	N=3,180 (%)
Sex				
Female	6,516 (19.5)	1,071 (10.1)	4,232 (21.5)	1,213 (38.1)
Age				
Median	24 (IQR [A] = 21)	33 (IQR = 17)	18 (IQR = 13)	30 (IQR = 40)
<25 yrs	17,318 (51.7)	1,926 (18.2)	13,936 (70.7)	1,456 (45.8)
25-55 yrs	13,661 (40.8)	8,188 (77.2)	4,579 (23.2)	894 (28.1)
>55 yrs	2,516 (7.5)	493 (4.6)	1,193 (6.1)	830 (26.1)
Injury Severity				
ISS [B] ≥16	4,253 (12.7)	1,385 (13.1)	2,325 (11.8)	543 (17.1)
Mortality				
Deceased	816 (2.4)	260 (2.5)	423 (2.1)	133 (4.2)

[A] Interquartile range
[B] Injury Severity Score

Injury severity

Severe trauma was diagnosed in 13.1% of the motorcyclists, 11.8% of the moped riders and 17.1% of the light-moped riders (Table 2). Overall, severe trauma was most prevalent in the light-moped rider group (adjusted RR 1.46). In all age categories severe trauma was most prevalent in the light-moped rider group: especially in light-moped riders older than 55 years (RR 1.79) (Table 3).

Despite the increasing number of motorcycle owners during our study period, the annual number of hospital admissions after motorcycle crashes decreased. The percentage of severe trauma remained approximately equal over the years. The situation for the moped riders was similar. After a decrease in admissions of light-moped riders, the number of admissions remained stable during the onward studied years. Even a slight increase was seen at the end of our study period (Figure 1).

Table 2. Mantel Haenszel risk ratios of severe trauma (ISS ≥ 16) and mortality for three groups of hospital admitted MTV crash victims.

			MH risk ratio°		MH risk ratio *	
		N	RR#	95% CI ‘	RR	95% CI
ISS ≥ 16	Motorcycle	1385	1.11	1.04 - 1.18	1.14	1.06 - 1.23
	Moped	2325	1	Ref	1	Ref
	Light-moped	543	1.45	1.33 - 1.58	1.46	1.33 - 1.60
Mortality	Motorcycle	260	1.14	0.98 - 1.33	1.12	0.94 - 1.33
	Moped	423	1	Ref	1	Ref
	Light-moped	133	1.95	1.61 - 2.36	1.49	1.21 - 1.83

Moped riders were used as reference group
° Crude MH risk ratios per type of motorized two-wheeled vehicle.
* MH risk ratios adjusted for age and sex per type of motorized two-wheeled vehicle
# Risk Ratio
‘ Confidence Interval

Table 3. Mantel Haenszel risk ratios of severe trauma (ISS ≥16) and mortality per age category adjusted for sex divided in three groups of hospital admitted MTV crash victims.

			< 25 yrs		25 - 55 yrs		> 55 yrs	
		N	RRmh#	95% CI ‘	RRmh	95% CI	RRmh	95% CI
ISS ≥ 16	Motorcycle	1385	1.19	1.06 - 1.34	1.13	1.02 - 1.25	1.05	0.80 - 1.38
	Moped	2325	1	Ref	1	Ref	1	Ref
	Light-moped	543	1.34	1.17 - 1.52	1.44	1.20 - 1.71	1.79	1.47 - 2.18
Mortality	Motorcycle	260	1.64	1.24 - 2.16	1.13	0.88 - 1.45	0.36	0.19 - 0.65
	Moped	423	1	Ref	1	Ref	1	Ref
	Light-moped	133	1.31	0.91 - 1.87	1.86	1.24 - 2.80	1.45	1.06 - 1.99

Moped riders were used as reference group
Mantel-Haenszel Risk Ratio
‘ Confidence Interval

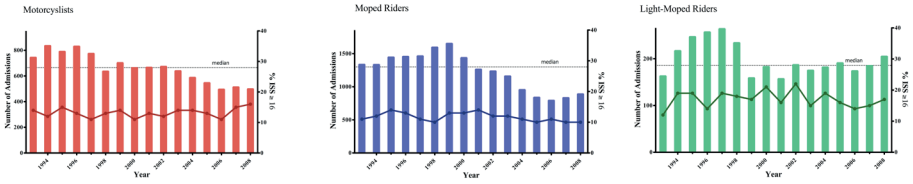

Fig 1. Number of crash victims admitted to hospitals across the Netherlands (coloured bars) per MTV group and the percentages of severe trauma (ISS ≥ 16) (coloured lines) per year during the period 1993-2008.

Injury pattern

As shown in figure 2, in the light-moped rider group head and face/neck injuries were the most common injuries sustained, respectively 32.2% and 11.3%. The most common injuries in the motorcyclist group were upper-extremity and spine injuries (25.7% and 5.9%). Moped riders were mostly diagnosed with a lower-extremity injury (37.5%, see Figure 2).

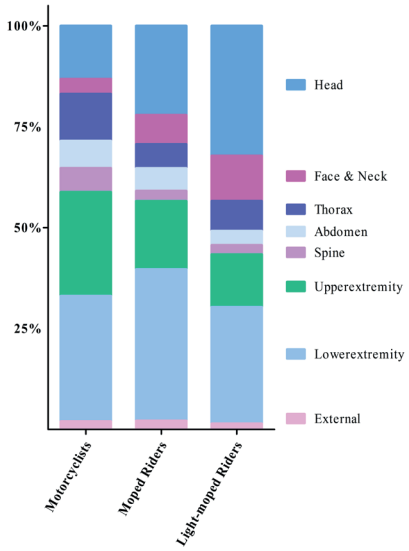

Fig. 2. Distribution of injuries per anatomical region (according to the AIS classification) in fatally and non-fatally injured motorized two-wheeled vehicle riders per MTV group. The External category comprises of burns.

In figure 3A only the most severe injuries were considered (AIS>2). In the light-moped rider group, nearly half of all severe injuries concerned head injury (49.3%). In the motorcyclist group, severe thorax injury and severe lower-extremity injury were most common (respectively 24.3% and 39,1%). In admitted moped riders severe lower extremity injury was most common (48.5%), followed by severe head injury (29.6%).

Mortality

Death after admission to the hospital was most prevalent in the light-moped group (4.2%). The relative risks of death upon hospital admission are displayed in table 2. Relative risks stratified per age category are displayed in table 3. Compared to the occurrence of severe trauma, a similar pattern was visible for mortality: when compared to moped riders, the risk of death was highest in light-moped riders (RR 1.49, 95%CI 1.21 – 1.83). When stratified for age, the risk of death following a motorcycle accident after admission to a hospital was highest in the youngest age category (RR 1.64, 95% CI 1.24 – 2.16). In advancing age categories, the risk of death was highest in light-moped riders.

The distribution of severe injuries among fatally injured riders per MTV group is displayed in figure 3B. Severe head injury was most frequently diagnosed in all three groups of MTV riders: 47% in motorcyclists, 64% in moped riders and 73% in light-moped riders who deceased. The second most common severe injury was thoracic injury: respectively 20%, 14% and 13%.

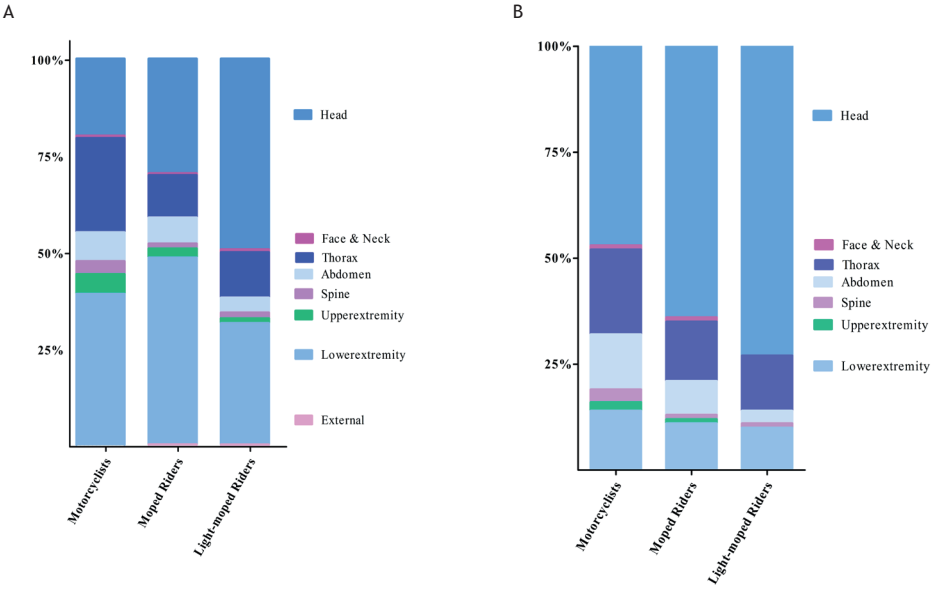

Fig. 3. Distribution of severe injuries per anatomical region (according to the AIS classification: AIS > 2) in non-fatally and fatally injured (A) and in fatally injured (B) motorized two-wheeled vehicle riders per MTV group.

DISCUSSION

This nationwide study aimed to describe the influence of the type of MTV on patient injury pattern, severity and mortality upon hospitalization after MTV accidents.

Important to note is that MTV groups were used as a proxy for several differences between these types of MTV: helmet use is not mandatory for light-moped drivers and the permitted maximum speed is of course different for each group of MTV (Light-mopeds 25 km/h, mopeds 45 km/h and motorcycles 120 km/h). In addition, the rider characteristics for the three classes differ in age and sex. Although we control for these two differences, all our results should be interpreted with the notion that MTV class is used as a proxy for these measures and therefore no definite conclusions can be drawn regarding one single property.

MTV crashes are associated with injuries in multiple anatomic regions and often result in instant death. This is largely due to their great vulnerability in daily traffic. In the Dutch situation, the light-moped can be seen as the most vulnerable MTV because helmet use is not mandatory by law. Our findings showed that driving a light-moped is associated with a high risk to sustain severe trauma and dying when admitted to a hospital after a crash compared to the better-protected motorcyclist and moped rider.

Interestingly, the present study shows a significantly higher risk of mortality after being involved in a traffic accident for motorcyclists younger than 25 years old, compared to moped and light-moped riders in the same age group. In contrast to the higher risk in the younger group of motorcyclists, advancing age in the light-moped group was associated with worse outcomes. Especially light-moped riders aged 55 years and older were significantly more likely to suffer severe injury and death compared to hospital-admitted moped riders and motorcyclists. Younger riders may have less experience in riding a motorized vehicle, more easily overestimate their riding skills and are more prone to accept excessive risks. Another influence might be the phenomenon of illegally upgraded engines in mopeds and light-mopeds, especially by younger riders. In 2007, 22% of the moped and light-moped riders halted by Police forces on Dutch roads were driving illegally upgraded mopeds and light-mopeds. This percentage was the same as in 2006, but lower than in 2005 (28%) and 2004 (31%). [14] Although a decrease was seen in the number of illegal modifications of mopeds and light-mopeds, these modifications still might increase the risk of crashes because of higher driving speeds.

Older riders are, in general, more careful on the road, but they are physically more vulnerable. Several governmental reports and scientific studies also suggested that advancing age might be associated with higher risks of suffering severe extensive injury and mortality.[4, 8, 15-17]

Our findings concerning injury pattern and injury severity may hold important implications for the treatment of MTV crash victims and the prevention of severe injury and mortality after crashes. The results of this study showed that motorized two-wheeled accidents are often associated with injuries in multiple anatomic areas. Besides head injuries, many injuries to the trunk, abdomen and extremities were registered. Therefore, the MTV crash victim can be seen as a complex trauma patient who needs an adequate poly-trauma evaluation and management by specialised healthcare personnel, both pre-hospital and hospital personnel. Moreover, the seemingly simple and low-energy light-moped crashes result in substantial injury or death relatively more frequent than in other MTV crashes. Therefore, especially for these light-moped crash victims, extra care should be taken on beforehand, so as not to underestimate their potential injuries

and their sequels. Even though, their primary presentation may not be as impressive as that of a motorcycle crash victim. Bearing this in mind, low threshold admittance to a trauma centre facility may be advisable.

During our study period, a total of 1,342 motorcycle, 973 moped and 323 light-moped-related deaths were registered in the Netherlands.[5, 6, 14, 18] On average, 31% of these deaths occurred after hospitalization (motorcyclists 19%, moped riders 43%, light-moped riders 42%), and the other 69% of the deceased MTV crash victims died before they arrived at the hospital. Since medical staff in emergency rooms, operating theatres and intensive care units, will treat patients who only survive the initial crash, we designed this study to describe the injury pattern and severity amongst MTV crash victims after hospitalization. Therefore, the risks and injury patterns described here are large underestimations of the absolute mortality risks associated with MTV crashes, especially for motorcyclists (81% of the deceased motorcyclists died before arrival at the hospital). The percentage of victims who died before hospitalization (57% of the deceased) is equal for moped and light-moped riders, which reduces the bias in these calculations. Nonetheless, the current results should be interpreted with this selection in mind and cannot be used to draw conclusions on the absolute risks of motorised two-wheeled vehicle use.

The percentage of severe head injury upon hospitalization was most frequent in both non-fatally and fatally injured light-moped crash victims and lowest in motorcycle crash victims. Assuming that motorcyclists with severe head injury are more prone to die at the scene of the accident because of the high-energy trauma mechanism, the protective effect of helmets on head injury can probably account for the relatively low amount of severe head injury in hospitalized motorcyclists. When the initial severe head trauma was survived, motorcyclists probably died because of other severe trauma after hospitalization. This could implicate that a large proportion of severe head injuries in light-moped riders could have been prevented with the usage of protective helmets.

The protective effect of helmets has been confirmed in many studies regarding helmet use on MTV's.[1-4, 9, 15, 19-21] Furthermore, the trend of prevention of head injury is already accepted in sports in which the athlete is at a higher risk of sustaining a head injury, such as skiing[22, 23] and cycling[24]. But our data point out that apart from head injury, thoracic injury, abdominal injury and extremity injury also represent a high percentage of sustained injury and severe injury in the non-fatally and fatally injured MTV rider.

The present study, therefore, indicates that it is important to not only strive for strict helmet usage to prevent brain damage for all types of motorized two-wheelers but

that the protection of other vital organs in the chest and abdomen is just as important. Continued improvement of existing MTV rider safety measurements and risk perception is of major importance. Mandatory protective and striking clothing, educational improvement and improvement of road conditions are additional measures that could improve MTV rider safety.

As a result of the increased numbers of MTV owners and to improve traffic safety in the Netherlands, several governmental protective and preventive measures were introduced during the study period. In 1998 the Ministry of Health, Welfare and Sport designated 11 hospitals across the country as Level 1 trauma centres. Their goal was to regionalize and deliver the full spectrum of healthcare to an injured patient. This strategy of regionalized expert trauma care has shown to be both efficient and cost-effective.[25] Since 1998 a growing number of MTV crash victims were transported directly to Level 1 trauma centres in the Netherlands. Through the implementation of more efficient prehospital triage systems and improved prehospital care, regionalized trauma care may have attributed to the initial decline in hospital admissions, although the percentage of severe trauma remained at a stable level (figure 1).

A limitation of this study is the absence of complete and reliable data on helmet use. It is assumed that 100% of motorcyclists use motorcycle helmets and less than 10% of light-moped riders. The true impact of helmet use cannot, therefore, be interpreted in this study. Liu et al estimated that motorcycle helmets reduce the risk of head injury by 69% and death by 42%. Another limitation is the absence of information on whether the crash victims were the driver or the passenger. Also, the number of safety features present on the different vehicles which were involved in the MTV crashes was not available.

Although every effort was made to code injuries accurately, a possible bias might have been introduced concerning the interpretation of injury pattern, injury outcome and accident demographics; therefore, influencing the AIS and ISS coding. Also, cases in which the local authorities registered a hospital visit and this was not registered by the hospital, and vice versa, were not included in the database.

This study presents an analysis of the current situation in The Netherlands concerning injury pattern, injury severity and mortality among hospitalized motorized two-wheeled vehicle crash victims. Overall, the hospital admitted light-moped riders show more severe head injuries and higher mortality than moped riders and motorcyclists. The young motorcycle rider and elderly light-moped rider are two very vulnerable groups in daily MTV traffic, with the highest chances of severe injury and mortality, upon hospitalization. The differences in age and also the use of different types of motorized

two-wheeled vehicles are of significant importance, both medically and socially. This study points out that despite previous protective measurements continuing improvement of the safety of all MTVs is urgent.

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