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Clinical and forensic significance of hand injuries incurred through mechanisms of indirect force with users of two wheeled vehicles

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Clinical and forensic significance of hand injuries incurred through mechanisms of indirect force with users of two-wheeled vehicles. Our aim is to explore and verify injuries resulting from the effect of indirect force, the clinical significance of which is small or insignificant in terms of their severity, but which have great significance in terms of expertise, primarily as a medical element in the reconstruction of the flow of traffic collisions and the complex dynamics of body movement of this unstable vehicles' users. Hand injuries among users of two-wheelers may arise as a result of contact with the handlebars, when the hands (back of the hands) collide with the metal grips of the hand brake and clutch, or anytime the handlebars "wedge" into the space between the thumb and forefinger. In comparison with pedestrians, as a control group, a statistically significant difference was established in the incidence of hand injuries in motorcycle drivers.

Keywords: hand injuries; two-wheelers; clinical significance; forensic significance

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Economic development, scientific and technological advances and other factors have contributed to the increased number of vehicles, drivers and also accidents. Besides the benefits that traffic as one of the achievements of civilization undoubtedly brings, its rapid development carries great risks, such as environmental pollution, and a direct hazard for human health and life, which is reflected in the large number of injured people[1,2]). The number of motorcycles is increasing worldwide, particularly in developing countries. A World Health Organisation (WHO) study on the Americas concluded that in countries like Brazil, Mexico, Canada and the United States, motorcycle crashes are responsible for 20-30% of all deaths due to trauma. In Singapore, motorcycle crashes are responsible for 54% of all deaths caused by any motor vehicle accidents. In Italy in 1997, 20% of all deaths due to traffic accidents involved motorcycles while in the United States the number of deaths due to motorcycle crash increased 103% between 1997 and 2006, numbering 2300 deaths in 1994 and 4000 in 2004.[4,5] In the United Kingdom in 1998 motorcycle crashes were responsible for 15% of all deaths or serious injuries by traffic accidents.[4]

In line with the complex motion dynamics of these vehicles, the subject of research are primarily the medicolegal characteristics of injuries caused by the indirect mechanisms of force. During the multiple phases of a collision, these forces are particularly manifested in the phase of the body being thrown onto the vehicle as well as the stage

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of the fall, where the head hits the ground thereby exerting particular force on the neck, with the simultaneous transmission of forces on to the contents of the skull, and the bones of the skull base.[3,4] Hyperextension forces, forced flexion, rotation, traction force along with the accompanying so-called horizontal deceleration forces, can cause serious injuries to users of two-wheelers. These injuries are most frequently the result of a combination of the effects of these forces seriously affecting the neck, which, because of it high mobility and relatively poor stability, is one of the most vulnerable parts of the body in two-wheeler traffic collisions. The standard technical protection that is in use, especially helmets, does not efficiently prevent injuries in this region.[1,2,4]

Working hypothesis and objective

Our aim is to explore and verify injuries resulting from the effect of indirect force, the clinical significance of which is small or insignificant in terms of their severity, but which have great significance in terms of expertise, primarily as a medical element in the reconstruction of the flow of traffic accidents and the complex dynamics of body movement of this unstable vehicle users. Special stress is put on hand injuries which constitute an important element conducive to medicolegal solution to driver-or-passenger dilemma. Their frequency is compared to known data relating to the injury of pedestrians, who act as the control group.

The available literature shows that the injury of two-wheeler users is most often discussed in the context of epidemiological studies, with no comprehensive analysis of the characteristics and mechanisms of injuries.[2–5] With this in mind, we thought the research of this pathology, through a representative sample of cases (502 cases), would find a practical application in everyday expertise practice relating to two-wheeler collisions.

Material and Methods

Analysed sample and the basic principles of research

The research is based on an analysis of autopsy material of The Institute of Forensic Medicine in Belgrade which covers twelve years, from 1990 to 2003. A total of 502 autopsy reports of two-wheeler fatalities were analysed (drivers and passengers of motorcycles and mopeds as well as cyclists). A part of the research was carried out on the sample of 222 autopsy reports (excluding cyclists) covering the territory of Serbia, mainly the city of Belgrade.

During the course of reconstructing collisions for each case, the autopsy analysis of the character of the injuries suffered in comparison with the data that was contained in the documents obtained from the investigating authorities (minutes of the examinations, the scene) were certainly of the greatest importance, as well as post-mortem data from surveys that are an integral part of every forensic autopsy report. Also, in some cases, the macroscopic autopsy report was supplemented by histopathological and other laboratory-toxicological analyses of the material that is taken during the autopsy.

In cases where fatally injured users of two-wheelers outlived their injuries for a longer or shorter time and were treated at health institutions the information contained in the medical records was studied in detail.

Bearing in mind the common disproportion of external and internal findings, which is one of the characteristics of traffic trauma in general, in all cases a series of modified (i.e. special) autopsy techniques were applied that allow the identification of those

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injuries that could be overlooked, altered or damaged, during usual autopsy procedures. They primarily represent the incision of the skin and preparing the subcutaneous soft tissue, access to bones, joints and neurovascular structures, in places where there are no external injuries but can be empirically assumed to be present.

In addition, a special forensic autopsy has a detailed overview and description of biological and other traces found on the body of the corpse (the presence of particles of glass, earth, fallen varnish from the damaged vehicles, etc.). All of the above also applies to the detailed examination of clothes, which, as well as footwear, are described in detail in terms of the existence of soiling and / or tearing, insisting on their exact localization, their size, shape and other characteristics.

All of the above was entered into a specially designed database in the programme Acess. After the analysis of the obtained data, the results were tabulated and presented graphically and processed using standard statistical methods.

- In this paper the following methods of descriptive statistics were applied:
- Measures of central tendency: mean (x)
- Measures of variability interval of variation (max-min) and standard deviation (sd);
- Relative numbers;
- The methods of analytical statistics used in the paper were:
- Identification of empirical distribution
- Methods for assessing the importance of differences:
- The Chi-square test (χ^2 test);
- Single factor numerical analyses of variance ANOVA
- Single factor analyses of variance (ANOVA) for attributive characteristics

Characteristic localization of injuries in users of two-wheelers

In traffic trauma in general, and in two-wheeler collisions, finding so called characteristic injuries has undoubted importance. Although the severity of these injuries compared to the overall state of injury is small, their forensic significance is huge in terms of the interpretation of the mechanism of injury, or the dynamics of how the collision played out. Finding an injury of this localization may, among other things, answer the question of whether a person was on the two-wheeler or was next to it at the moment the accident, in which case they were injured as a pedestrian. Also, certain injuries of characteristic localization can be of great importance in determining the sitting position on a two-wheeler, i.e. the medico-legal identification of the person as a driver or passenger at the time of the collision. In many cases, the imperative of examination is precisely providing answers to these questions.[1–3]

In this category of road users we singled out the characteristic injuries which we could reasonably assume may arise from contact of the body with some prominent parts of two-wheelers. Parts of two-wheelers, the contact with which leads to the formation of prominent trauma are: the seat and fuel tank (the motorcycle), or pedal pins and parts, steering wheel and handlebars, other parts of the side frame of the vehicle and the like. In types of motorcycles that have a windshield it is possible to find injuries caused by its upper edge.

A person driving a two wheeler may notice imminent danger and reflexively make a series of defensive motions. These motions are mainly made up of placing a tight grip

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on the handlebars, tightening the legs around the sides of the two-wheeler with strong pressure on the pedals or gas pedals with motorcycles. When the collision energy or some other influence disturbs the balance of the driver-vehicle system and overcomes the driver's muscular force the body is separated from the two-wheeler, after which, at this stage, it is in contact with the above mentioned trauma inducing parts.

On the other hand, the view of the passenger on the two-wheeler (motorcycle, moped) is obscured by the body of the driver, and they usually cannot notice the incoming danger or be prepared to defend themselves from the consequences of a collision. Their unstable position is caused, among other things, by their inability to hold on to the solid parts of the motorcycle, there is no other possibility of creating a firm grip on the vehicle which would allow for the reduction of the intensity of impact forces besides holding on to the driver's body. Therefore, a passenger on a motorcycle (moped) has a small chance of receiving some of the characteristic injuries to which drivers are more exposed (eg, tank, windshield). In such a situation with a direct frontal collision of vehicles moving in opposite directions, with high speeds of participating vehicles, the length of the flight of the passenger after being catapulted is longer than that of the driver.[1,3]

Hand injuries in users of two-wheelers

The hands are a protruding part of the body that are often exposed to injuries among users of two-wheelers, at almost all stages of the dynamics of body movement when it has been thrown out of balance. They can occur through contact with trauma inducing parts of the handlebars, and during the fall, where they often fist come into contact with the ground (Figure 1).

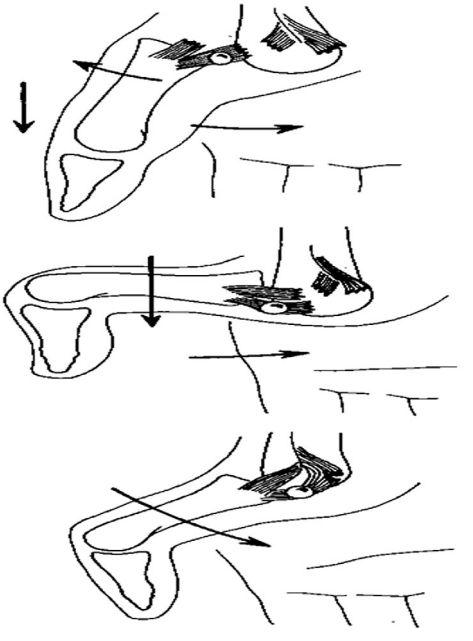

Figure 1. Wrench metakarpofalangial joint (the force direction) 3. Taken from reference 5 with the author's consent.

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Table 1. Percentage of external hand injuries in various road accident participants ir hand often s.

	Pedestrian	Car driver	Passenger car.	Rear left passenger	Rear right passenger	Driver passenger motor engine	Passenger motor engine
Fists	18.1%	21.4%	22.0%	13.2%	13.6%	50.3%	35.5%

In comparison with other participants in traffic accidents, hands injuries are more often seen in users of motorcycles and mopeds as shown in Table 1.

Features of hand (and other body part) injuries incurred at the stage of fall often reflect the characteristics of the surface on which the traffic accident took place. Because of the fall onto the extended arm, they are in some cases accompanied by indirect fractures of the forearm bones, most commonly distal spokes typical site (fracture radii loco tipico) isolated or associated with the extension of lactic styloid bone.[6,7]

Hand injuries can also occur in the first phase of a traffic accident at the moment of firm reflexive tightening of handlebars which support the driver's body, when the forced palmar hyperflexion of hands induces the contact between the back of the hand and the hand brake or clutch metal grips. Hand injuries thus caused were the subject of our study as part of characteristic injuries suffered by motorcyclists. Tables 2 and 3 show the findings of our research into the presence of external and internal hand injuries in motorcycle drivers and passengers on the sample of 222 autopsies.

Table 2 and 3 show that the injuries on the back of the hand are present in slightly more than half of the cases (50.3%) of motorcycle and moped drivers as well as in more than a third of passengers (35.5%).

In a subgroup of drivers and passengers killed in collisions from the front or due to the impact with an immovable obstacle (tab. 16 and 17), a significantly higher percentage of hand injuries is observed in drivers (78.9%) compared to the passengers (27.8%) which constitutes a statistically significant difference (Yates corected *chisq* 15,544; $p < 0.01$).

Table 2. External hand injuries in drivers.

(Drivers)	Frequency	Percentage
PRESENT	96	50.3%
∑	191	100%

Table 3. Internal hand injuries in passengers.

(Passenger)	Frequency	Percentage
PRESENT	11	35.5%
ABSENT	20	64.5%
∑	31	100%

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This data indicates that hand injuries in motorcycle collisions should be seriously analysed both when interpreting the mechanism of injury suffered by the participants, as well as in cases of medicolegal identification of the driver and the passenger.

In addition to external injuries, palmar forced flexion of the hand can cause subcutaneous soft tissue injuries, followed by injuries to the ligaments and wrist distortion; therefore we recommend that during autopsy hand skin should be incised and subcutaneous soft tissue, tendons and bones examined in detail. Even more so since motorcycle drivers wear driving gloves that can prevent the infliction of visible injuries on hand skin.

Given the distinctive position of the driver's hand on the motorcycle handlebars (thumb is fixed to the handle, while the other four fingers are mobile and operate the clutch and brake grips) joint dislocations are quiet likely. This especially so if in a collision the force is applied from the front or from the side, if there is a sudden turn of steering wheel all of which can result in an overstrained stretching (repositioning) of the thumb. We believe that these injuries are detected in surviving participants, however, their detection during autopsies may, inter alia, be of importance for medicolegal identification of the driver. We also believe that the autopsy technique should be modified in order to access the region, in order to establish such an injury.As a part of the so-called characteristic injuries, hand injuries can occur when drivers reflexively place a strong grip on the handlebars, which are one of the points where two-wheeler drivers place their weight. In the case of a collision, the hand and/or hands are in forced palmar hyperflexion and the back of their hands can make contact with the metal grips of the hand brake or the clutch of the motorcycle. In addition to external injuries, internal injuries such as dislocation or distortions may occur in this position. In literature the importance of carpometacarpal dislocations of the thumb are particularly emphasised in medicolegal identification of the person who was driving the motorcycle.[1,6–8] Given the distinctive position of the hand of motorcycle drivers on the handlebars (the thumb is placed around the lever, and the other four fingers are mobile and operate the brake or clutch), joint injuries are possible due to the "wedging" of the handlebars into the space between the thumb and forefinger (Figure 3).

With survivors the finding of this injury is possible with a clinical examination and an X-ray scan[3] and with deceased persons with an incision of the skin between the thumb and forefinger which is a part of the implementation of special autopsy techniques, especially if we know that both a driver and passenger participated in the collision. Another reason for using this technique is because, while driving, certain drivers of motorcycles wear protective gloves which can prevent visible injuries on the skin (Figure 2).

From Table 4 we can see that hand injuries are quite frequent with all analysed categories of two-wheeler users. A somewhat higher statistical presence can be observed in drivers of motorcycles which can be explained precisely by the trauma inducing effect of the handlebars which have a particularly marked effect in high-speed collisions.

This explanation was proven to be true in our previous study. When we analysed the prevalence of hand injuries in drivers and passengers of motorcycles and mopeds in situations where force is applied to the front part of the two-wheeler (frontal collisions with vehicles moving in the opposite direction and collisions with an immovable obstacle), when the trauma inducing effect of the impact of handlebars can be realistically expected, we found a statistically significant difference in the frequency of these injuries in favour of the driver who had this injury in 78.9% of cases

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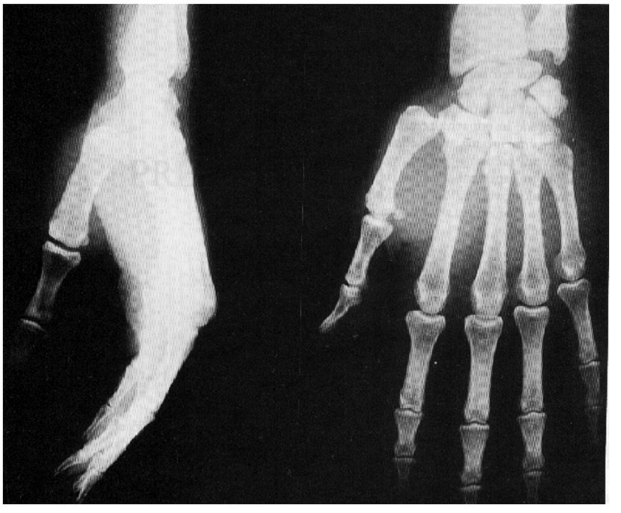

Figure 2. Photo: X-ray carpometacarpal dislocations of the thumb. Taken from reference 3 with the author's consent.

Table 4. Frequency of hand injuries in different categories of two-wheeler users.

	Motorcycle		Moped		
	Driver	Passenger	driver	passenger	Cyclist
With injury	51 (62.20%)	9 (52.94%)	37 (58.73%)	1 (25%)	176 (52.38%)
Without injury	31 (37.80%)	8 (47.06%)	26 (41.27%)	3 (75%)	160 (47.62%)
Total	82 (100%)	17 (100%)	63 (100%)	4 (100%)	336 (100%)

($\chi^2 = 15.544$; $p < 0.01$). Unlike drivers in these collision variants, these injuries in passengers were significantly less frequent (27.8%).[1] By comparing the frequency of hand injuries in motorcycle drivers in relation to pedestrians as the control group, a highly significant statistical risk of these injuries was established for motorcycle drivers ($\chi^2 = 93.081$; $p < 0.01$). Confidence interval is 0.95.

Discussion

In the relevant literature we found few articles which distinguish between drivers and passengers and their injuries in motorcycles collisions. Most articles deal with epidemiology of two-wheeler collisions and with dangerous, life threaten injuries. On demand at PubMed for key words; "hand injuries AND two-wheelers" the result was just 32 references. Gaheer's article reports a case of fracture of the base of the middle finger with dislocation of the ring and little finger carpometacarpal joints. Fracture dislocation of the carpometacarpal joints on the ulnar side of the hand is an uncommon injury. These are high-energy injuries seen in motorcyclists and boxers. The mechanism of injury involves violent, forceful dorsiflexion of the wrist combined with longitudinal impact on the closed hand. This article reports a case of fracture of the base of the middle finger with dislocation of the ring and little finger carpometacarpal joints.[6–9]

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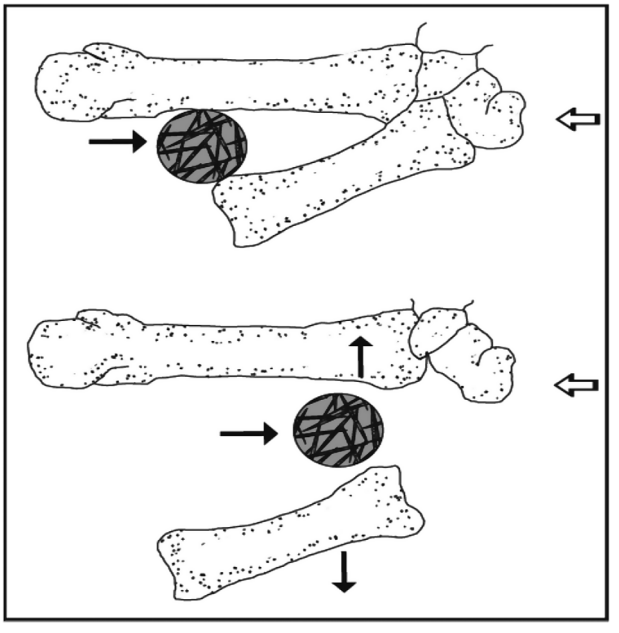

Figure 3. Injury caused by the handlebar to the region between the thumb and forefinger [3].

Conclusion

By studying the autopsy material of the Institute for Forensic Medicine in Belgrade spanning twelve years, which refers to fatalities of two-wheeler users the following conclusions were come by:

In collision expertise where two-wheelers participate injuries of characteristic localization caused by trauma inducing prominent parts of the vehicle are of special forensic significance (handlebars, prominent lateral parts of the motorcycle, windshield, etc.). The finding of these, along with other established facts, can be crucial in determining who was the driver and who was the passenger. On the other hand, these injuries are important in the differential diagnosis of pedestrians (when the person was next to the two-wheeler, not on it).

Hand injuries among users of two-wheelers may arise as a result of contact with the handlebars, when the hands (back of the hands) collide with the metal grips of the hand brake and clutch, or anytime the handlebars "wedge" into the space between the thumb and forefinger.

In the cases of a frontal collision with vehicles moving in opposite directions and impact with an immovable obstacle, when trauma inducing impact with the handlebars can be realistically expected, a statistically significant difference in the incidence of these injuries in driver (78.90%) was established compared to passengers. In comparison with pedestrians, as a control group, a statistically significant difference was established in the incidence of hand injuries in motorcycle drivers.

Disclosure statement

No potential conflict of interest was reported by the authors.

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