M. Richter, D. Otte, C. Haasper, K. Sommer,
K. Knobloch, C. Probst, J. Westhoff, C. Krettek
Hannover Medical School, Hannover, Germany

The Current Injury Situation of Bicyclists – A Medical and Technical Accident Analysis

Abstract

Bicyclists are minimally or unprotected road users. Their vulnerability results in a high injury risk despite their relatively low own speed. However, the actual injury situation of bicyclists has not been investigated very well so far. The purpose of this study was to analyze the actual injury situation of bicyclists in Germany to create a basis for effective preventive measures.

Technical and medical data were prospectively collected shortly after the accident at the accident scenes and medical institutions providing care for the injured. Data of injured bicyclists from 1985 to 2003 were analyzed for the following parameters: collision opponent, collision type, collision speed (km/h), Abbreviated Injury Scale (AIS), Maximum AIS (MAIS), incidence of polytrauma (Injury Severity Score >16), incidence of death (death before end of first hospital stay).

4,264 injured bicyclists were included. 55% were male and 45% female. The age was grouped to preschool age in 0.9%, 6 to 12 years in 10.8%, 13 to 17 years in 10.4%, 18 to 64 years in 64.7%, and over 64 years in 13.2%. The MAIS was 1 in 78.8%, 2 in 17.0%, 3 in 3.0%, 4 in 0.6%, 5 in 0.4%, and 6 in 0.2%. The incidence of polytrauma was 0.9%, and the incidence of death was 0.5%. The incidence of injuries to different body regions was as follows: head, 47.8%; neck, 5.2%, thorax, 21%; upper extremities, 46.3%; abdomen, 5.8%; pelvis, 11.5%, lower extremities, 62.1%. The accident location was urban in 95.2%, and rural in 4.8%. The accidents happened during daylight in 82.4%, during night in 12.2%, and during dawn/dusk in 5.3%. The road situation was as follows: straight, 27.3%; bend, 3.0%; junction, 32.0%; crossing, 26.4%; gate, 5.9%; others, 5.4%. The collision opponents were cars in 65.8%, trucks in 7.2%, bicycles in 7.4%, standing objects in 8.8%, multiple objects in 4.3%, and others in 6.5%. The collision speed was grouped <31 in 77.9%, 31-50 in 4.9%, 51-70 in 3.7%, and >70 in 1.5%. The helmet use rate was 1.5%. 68% of the registered head injuries were located in the effective helmet protection area.

In bicyclists, head and extremities are at high risk for injuries. The helmet use rate is unsatisfactorily low. Remarkably, two thirds of the head injuries could have been prevented by helmets. Accidents are concentrated to crossings, junctions and gates. A significant lower mean injury severity was observed in victims using separate bicycle lanes. These results do strongly support the extension or addition of bicycle lanes and their consequent use. However, the lanes are frequently interrupted at crossings and junctions. This emphasizes also the important endangering of bicyclists coming from crossings, junctions and gates, i.e. all situations in which contact of bicyclists to motorized vehicles is possible. Redesigning junctions and bicycle traffic lanes to minimize the possibility of this dangerous contact would be preventive measures. A more consequent helmet use and use and an extension of bicycle paths for a better separation of bicyclists and motorized vehicle would be simple but very effective preventive measures.

Introduction

Bicyclists are minimally or unprotected road users [1, 2]. Their vulnerability results in a high injury risk despite their relatively low own speed [1, 2]. However, the actual injury situation of bicyclists has not been investigated very well so far [3-8]. Most of the previous studies analyzed medical, police, and/or insurance records [3-6, 9-24]. An in-depth analysis of the crash circumstances is missing in principle. Under consideration of the results of previous studies with other priorities, we strongly believe that a technical in-depth crash investigation in combination with a medical data analysis is the most sufficient basis for an improvement of passive safety [1, 2, 25-29]. The purpose of this study was to analyze the actual injury situation of bicyclists in Germany to create a basis for effective preventive measures.

Methods

Since 1972, a local traffic accident research unit has collected prospective data in regard to all reported traffic accidents within Germany [1, 25, 30, 31]. Specially trained documentation personnel are notified by police dispatchers and arrive on scene, often simultaneously with the rescue personnel. Thus, investigation of the accident (measurements by photography, stereophotography, 3D-Laser-technique), and clinical injury documentation are performed on site [1, 25, 30-32]. This case report is then completed at the hospital, where all of the injured victims are taken, with proper documentation of x-ray examination, injury type and severity.

Among the technical measurement techniques, especially the modern 3D-Laser-technique is a quick and exact method to document the exact position of all objects at the crash site [32]. A three-dimensional data cube with a maximum size of $50m^3$ is generated from the data obtained by the 3D-Laser-scanner. This data allows an exactly scaled reconstruction of the accident site for later technical analysis of the crash. Sliding and skidding marks of vehicles, objects and victims and any kind of deformation of involved vehicles or objects are also measured, and these data are included in the crash analysis. Furthermore, data from a database containing technical features of involved vehicles (size, weight, detailed structural data comparable to finite element analysis data) are included in the analysis [32]. The inclusion of the described data in a software based calculation allows an exact estimation of parameters as Delta-v or collision speed [32]. The collision speed, for example, is calculated by inclusion of the following data: deformation sites and deformation extents at the colliding under consideration of the exact structural data of that vehicle; deformation sites and deformation extents of the bicycle; sliding and skidding distances, and exact end positions of the involved vehicles, bicyclist and other objects [2, 30, 32, 33].

In total, the monitoring of the accident research unit includes demographic data, type of road user (car/truck occupant, motorcyclist, cyclist, pedestrian), delta-v (km/h) for motorized vehicle user; vehicle collision speed (km/h) for bicyclists/pedestrians, Abbreviated Injury Scale (AIS), Maximum AIS (MAIS), Injury Severity Score (ISS), incidence of serious and/or severe multiple injuries (polytrauma, ISS >16), incidence of serious injuries (MAIS 2-4) or severe injuries (MAIS 5/6), and mortality [34, 35].

For this study, traffic accident reports with dates from 1985 to 2003 from the local traffic research unit, as described above, were analyzed for the involvement of injured bicyclists as well as for the following parameters: demographic data, AIS, MAIS, ISS, incidence of polytrauma, incidence of serious or severe injuries, incidence of death, collision speed, collision opponent, and collision type. For statistical analysis of the correlation between crash circumstances with injury severity (AIS, MAIS, ISS) a t-, Pearson- or Linear-Trend-test was used.

The study was approved by the Ethical Commission of the Hannover Medical School, Hannover, Germany, and the State of Lower Saxony, Germany.

Results

4,264 injured bicyclists were analyzed.

Demographic data

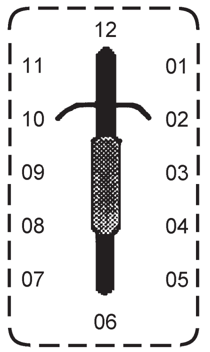
55% of bicyclists were male and 45% were female. The mean age of bicyclists was 52.0 (range, 4-83; standard deviation, 21.7) years. 0.9% were in preschool age, 10.8% were between 6 and 12 years old, 10.4% between 13 and 17, 64.7% between 18 and 64, and 13.2% were over 64 years old.

Crash circumstances

95.2% of accidents took place in urban areas, 4.8% in rural areas (Table 1). 55% of bicyclists used bicycle traffic lanes before the accident.

Road network location	
Straight	27.3%
Bend	3.0%
Junction	32.0%
Crossing	26.4%
Gate (junction to public road)	5.9%
Others	5.4%
Type of road	
Motorway	0.1%
Federal road	2.9%
Country road	6.6%
Street	68.4%
Parking lot	0.5%
Bicycle traffic lanes	16.8%
Playground	0.2%
Gate (accident located on gate)	1.2%
Others	3.3%

Table 1: Accident location in 4,264 injured bicyclists



1st impact	n	%
fall before	281	6,6
1 o'clock	119	2,8
2 o'clock	171	4
3 o'clock	516	12,1
4 o'clock	55	1,3
5 o'clock	55	1,3
6 o'clock	60	1,4
7 o'clock	81	1,9
8 o'clock	111	2,6
9 o'clock	849	19,9
10 o'clock	388	9,1
11 o'clock	303	7,1
12 o'clock	887	20,8
unknown	388	9,1

Figure 1: Direction of the first impact in 4,264 injured bicyclists

16.8% of crashes happened on bicycle traffic lanes. 82.5% of the accidents happened during daylight, 5.3% during dawn or dusk, and 12.2% during night or darkness. Collision opponents were cars in 65.8%, trucks in 7.2%, bicyclists in 7.4%, standing objects in 8.8%, multiple opponents or objects in 4.3%, and others in 6.5%. The mean collision speed was 21.3 (range, 0-123; standard deviation, 16.5)km/h. The collision speed amounted to less than 31km/h in 77.9%, between 31 and 50km/h in 4.9%, between 51 and 70km/h in 3.7% and above 70km/h in 1.5%. Figure 1 indicates the direction of the first impact at the victims' bicycles. 1.7% (n=78) of bicyclists were helmet protected.

Injuries

Table 2 indicates the MAIS and Table 3 the AIS of the different body regions. 79% of bicyclists sustained only injuries with minor severity (MAIS 1), and 4,2% at least one severe injury (MAIS 3+). The mean ISS was 3.87 (range, 1-75; standard deviation, 8.6). The incidence of polytrauma was 2.0% (n=84), and the incidence of death 1.5% (n=64). Fifty-eight victims (1.4%) died before reaching the medical institution, and six (0.1%) at a later stage during the initial hospital care. The lesions at the head in not helmet-protected bicyclists were located in 68% above the ear level, i.e. in the typical helmet protection area.

Correlation between crash circumstances and injury incidence and severity

A significant correlation of collision speed with AIS of all body regions, MAIS, and ISS occurred (Table 2, 3; Pearson-test <0.05). The collision speed was higher in victims with polytrauma or fatal injuries than in victims without (mean collision speed, polytrauma yes/no – 50.3/20.5km/h, t-test p<0.001; death yes/no – 52.3/20.8, t-test p<0.001).

	Collision speed (km/h)					
	in total (n=4,264)	<30 (n=3,321)	31-50 (n=209)	51-70 (n=158)	>70 (n=64)	unknown (n=511)
MAIS 1	78.8%	80.7%	66.5%	49.5%	33.7%	81.2%
MAIS 2	17.0%	16.5%	22.5%	29.5%	17.9%	15.6%
MAIS 3	3.0%	2.2%	7.2%	13.8%	15.7%	2.4%
MAIS 4	0.6%	0.3%	2.1%	3.4%	5.8%	0.5%
MAIS 5	0.4%	0.2%	1.5%	1.2%	15.7%	0.2%
MAIS 6	0.2%	0.1%	0.2%	2.5%	11.1%	0.0%

Table 2: MAIS and collision speed in 4,264 injured bicyclists

	Collision speed (km/h)				
	in total	<30	31-50	51-70	>70
Head					
not injured	53.2%	56.0%	35.8%	30.7%	18.0%
AIS 1	35.9%	34.9%	41.5%	31.4%	32.4%
AIS 2	9.3%	8.2%	18.0%	26.6%	15.8%
AIS 3+	1.6%	0.9%	4.7%	11.3%	33.8%
Neck					
not injured	95.6%	95.5%	95.4%	95.9%	87.6%
AIS 1	4.2%	4.3%	4.3%	2.9%	4.9%
AIS 2	0.1%	0.1%	0.2%	-	-
AIS 3+	0.1%	0.1%	0.1%	1.3%	7.5%
Thorax					
not injured	79.9%	80.7%	76.5%	65.3%	65.9%
AIS 1	16.1%	16.0%	14.8%	23.6%	7.3%
AIS 2	3.3%	3.0%	6.1%	7.0%	11.8%
AIS 3+	0.7%	0.4%	2.5%	4.1%	15.0%
Upper extremity					
not injured	54.2%	54.0%	53.3%	41.6%	30.8%
AIS 1	42.7%	43.2%	43.4%	53.6%	37.3%
AIS 2	2.7%	2.5%	2.8%	1.3%	18.6%
AIS 3+	0.3%	0.2%	0.6%	3.4%	13.3%
Abdomen not injured	95.1%	95.6%	89.7%	95.5%	82.8%
AIS 1	4.5%	4.1%	8.6%	2.8%	9.7%
AIS 2	0.2%	0.2%	1.1%	0.6%	-
AIS 3+	0.2%	0.2%	0.6%	1.1%	7.5%
Pelvis					
not injured	89.2%	90.2%	85.6%	89.8%	91.9%
AIS 1	10.2%	9.2%	12.6%	8.2%	1.1%
AIS 2	0.5%	0.3%	1.3%	1.4%	7.1%
AIS 3+	0.2%	0.2%	0.4%	0.6%	-
Lower extremity					
not injured	38.2%	37.4%	34.1%	25.0%	25.4%
AIS 1	56.0%	57.4%	55.7%	52.9%	44.1%
AIS 2	4.1%	3.9%	5.7%	11.0%	10.0%
AIS 3+	1.8%	1.3%	4.5%	11.1%	20.5%

Table 3: AIS of different body regions and collision speed in 4,264 injured bicyclists

Table 3 shows the incidence of injuries to the different body related to the impact speed of the opponent. The injury severity of nearly all the

	MAIS	ISS	Significance t-test
Helmet (n=78)	1.27±0.6	3.35±10.2	MAIS, p=0.02
No helmet (n=4,186)	1.46±0.8	3.97±8.7	ISS, p=0.05
Daylight (n=3,470)	1.43±0.8	3.82±8.6	MAIS, p=0.18
Darkness (n=537)	1.48±0.9	4.26±9.4	ISS, p=0.28
Urban (n=3,980)	1.41±0.9	3.60±7.8	MAIS, p<0.001
Rural (n=284)	1.83±1.1	7.6±15.0	ISS, p<0.001
Bicycle traffic lane used (n=2,348)	1.34±0.7	3.17±7.4	MAIS, p<0.001
No bicycle traffic lanes (n=1,916)	1.57±0.9	4.75±9.7	ISS, p<0.001
Road without junction etc. (n=1,339)	1.51±0.9	4.41±9.6	MAIS, p<0.001
Junction, crossing, gate etc. (n=2,910)	1.41±08	3.6±8.1	ISS, p=0.005

Table 4: Injury severity (MAIS, AIS, ISS) in different crash situations in 4,264 injured bicyclists. Mean values and standard deviations are indicated

different body regions was influenced by the impact speed, but especially head and lower extremity are at high risk in crashes with collision speed above 50km/h.

Table 4 shows the injury severity (MAIS, ISS) under different crash circumstances. Lower injury severity (MAIS, ISS) occurred in victims with a helmet, with crashes in urban areas and those who used bicycle lanes than in victims without helmet, crashes in rural areas and not using bicycle traffic lanes.

Discussion

In this study, a technical and medical in-depth investigation of more than 4,000 vehicular crashes with consequent injuries to bicyclists was performed. This study was focused on crash circumstances and epidemiologic data. Injury mechanisms were analyzed in further detail except an assessment of the bicycle helmet. The purpose of this analysis was to analyze the injury causes far beyond the numerous previous epidemiologic studies [3-6, 9-24].

In an earlier study, we demonstrated the high vulnerability to injury among the unprotected road users such as the pedestrians and bicycle users in children and adolescents [1]. The methodology of the data acquisition was discussed before [25, 26, 33, 36].

Special injury situation of bicyclists

In bicyclists, head and extremities are at high risk for injuries especially in high speed accidents (collision speed above 50km/h). Almost half of the injured bicyclists sustained head and/or upper extremity injuries, and almost two thirds sustained injuries of the lower extremities. These body regions are more endangered than in car occupants [1, 25, 27, 29]. Furthermore, a higher injury severity (ISS, MAIS) and mortality rates were seen in bicyclists.

The impact of head injuries is underlined by the high percentage of inpatient treatment among the group who sustained head injuries [37, 38]. A bicycle helmet has been shown to significantly decrease the risk and offer sufficient protection against head injuries [1]. Only 1.7% of the injured bicyclists were helmet protected in our study. This percentage was observed for the entire sample. Fortunately the helmet protection rate increased over the investigated period (data not shown). The helmet protection rate was higher for children than for adolescents and adults (data not shown). Approximately two thirds of the impact locations as witnessed on the heads of the bicycle victims had been in the areas that would have been protected with the use of a bicycle helmet. Consequently, mandatory regulations requiring bicycle helmet use would be a promising measure in the prevention of head injuries to bicyclists. Of course, only helmets fulfilling the Snell or ANSI standard would be adequate for the protection of injuries [24, 39-47].

The high percentage of lower extremity injuries as seen in collisions with cars demands further analysis of this type of crash scenario. The forces induced by the bumpers of cars and especially trucks, result in a high bending moment at the level of the knee and the proximal tibia. An alteration in design of vehicle bumpers with increased padding for example or with exterior airbags may reduce the frequency and/or severity of these injuries. Other promising preventive measures for the lower extremity are protective pads or clothes including pads as developed for motorcyclists [48]. In an earlier study, we demonstrated that protectors for motorcyclists could reduce the load to the tibia in bumper impacts sufficiently [48]. However, the acceptance of bicyclists' additional pads or clothes is at least as problematic as of helmets [1, 48].

Another important factor is speed, since the injury severity is increasing rapidly at collision speeds above 50km/h. Additional speed limits in areas with "bicycle traffic" should be considered as a useful measure to reduce injury severity in bicyclists.

A significant lower mean injury severity was observed in victims using separate bicycle lanes. These results do strongly support the extension or addition of bicycle lanes and their consequent use. However, the lanes are frequently interrupted at crossings and junctions. This explains why more than two thirds of the bicyclists that had used bicycle lanes before crash were then involved in a crash out of the bicycle lane. This emphasizes also the important endangering of bicyclists coming from crossings, junctions and gates, i.e. all situations in which contact of bicyclists to motorized vehicles is possible. Redesigning junctions and bicycle traffic lanes to minimize the possibility of this dangerous contact would be preventive measures.

In conclusion, in bicyclists, head and extremities are at high risk for injuries. The helmet use rate is unsatisfactorily low. Remarkably, two thirds of the head injuries could have been prevented by helmets. Accidents are concentrated to crossings, junctions and gates.

A more consequent helmet use and use and an extension of bicycle traffic lanes for a better separation of bicyclists and motorized vehicle would be simple but very effective preventive measures.

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References

[1] M. RICHTER, D. OTTE, H.C. PAPE et al.: Current Situation of Road Traffic Accidents in Infants and Adolescents – A Medical and Technical Analysis. J Orthop Trauma. 2002;16:70-71

[2] M. RICHTER, H.C. PAPE, D. OTTE et al.: The current status of road user injuries among the elderly in Germany: a medical and technical accident analysis. J Trauma. 2005;58:591-595

[3] S.J. ASHBAUGH, M.L. MacKNIN, M.S. VANDERBRUG: The Ohio Bicycle Injury Study. Clin Pediatr (Phila). 1995;34:256-260

[4] S. LINN, D .SMITH, S. SHEPS: Epidemiology of bicycle injury, head injury, and helmet use among children in British Columbia: a five year descriptive study. Canadian Hospitals Injury, Reporting and Prevention Program (CHIRPP). Inj Prev. 1998;4:122-125

[5] H.W. ORTEGA, B.J. SHIELDS, G.A. SMITH: Bicycle-related injuries to children and parental attitudes regarding bicycle safety. Clin Pediatr (Phila). 2004;43:251-259

[6] B.H. ROWE, A.M. ROWE, G.W. BOTA:. Bicyclist and environmental factors associated with fatal bicycle-related trauma in Ontario. CMAJ. 1995;152:45-53

[7] D. OTTE: A review of different kinematic forms in two wheel accidents – their influence on injuries and effectiveness for protective measures. SAE Transaction 801314, Detroit, USA , 561-605. 1980.

[8] D. OTTE, E.G. SUREN: Der Fahrradunfall – Eine verkehrsmedizinisch-technische Analyse. Heidelberg: 1986

[9] E. MISSONI, J. KERN: Fatality risk factors for bicyclists in Croatia. Croat Med J. 2003;44:610-613

[10] E.K. MOLL, A.J. DONOGHUE, E.R. ALPERN et al.: Child bicyclist injuries: are we obtaining enough information in the emergency department chart? Inj Prev. 2002;8:165-169

[11] F.K. WINSTON, J. POSNER, E. ALPERN et al.: Who can give a pediatric trauma history for children injured in bicycle crashes? Annu Proc Assoc Adv Automot Med. 2000;44: 459-69

[12] .PK. DHILLON, A.S. LIGHTSTONE, C. PEEK-ASA et al.: Assessment of hospital and police ascertainment of automobile versus childhood pedestrian and bicyclist collisions. Accid Anal Prev. 2001;33:529-537

[13] R. EKMAN, G. WELANDER, L. SVANSTROM et al.: Bicycle-related injuries among the elderly – a new epidemic? Public Health. 2001;115:38-43

[14] J.C. STUTTS, W.W. HUNTER: Motor vehicle and roadway factors in pedestrian and bicyclist injuries: an examination based on emergency department data. Accid Anal Prev. 1999;31:505-514

[15] M.S. DURKIN, D. LARAQUE, I. LUBMAN et al.: Epidemiology and prevention of traffic injuries to urban children and adolescents. Pediatrics. 1999;103:e74

[16] G. LI, S.P. BAKER: Injuries to bicyclists in Wuhan, People's Republic of China. Am J Public Health. 1997;87:1049-1052

[17] C. FARRIS, D.W. SPAITE, E.A. CRISS et al.: Observational evaluation of compliance with traffic regulations among helmeted and nonhelmeted bicyclists. Ann Emerg Med. 1997;29:625-629

[18] B. YTTERSTAD: The Harstad injury prevention study: hospital-based injury recording used for outcome evaluation of community-based prevention of bicyclist and pedestrian injury. Scand J Prim Health Care. 1995;13:141-149

[19] G.B. RODGERS: Bicyclist deaths and fatality risk patterns. Accid Anal Prev. 1995;27:215-223

[20] F.P. RIVARA, R.V. MAIER, B.A. MUELLER et al.: Evaluation of potentially preventable deaths among pedestrian and bicyclist fatalities. JAMA. 1989;261:566-570

[21] S.M. SELBST, D. ALEXANDER, R. RUDDY: Bicycle-related injuries. Am J Dis Child. 1987;141:140-144

[22] K.S. HANSEN, G.E. EIDE, E. OMENAAS et al.: Bicycle-related injuries among young children related to age at debut of cycling. Accid Anal Prev. 2005;37:71-75

[23] A. COOK, A .SHEIKH: Trends in serious head injuries among English cyclists and pedestrians. Inj Prev. 2003;9:266-267

[24] G.W. PARKINSON, K.E. HIKE: Bicycle helmet assessment during well visits reveals severe shortcomings in condition and fit. Pediatrics. 2003;112:320-323

[25] M. RICHTER, H. THERMANN, B. WIPPERMANN et al.: Foot fractures in restrained front seat car occupants: a long-term study over twenty-three years. J Orthop Trauma. 2001;15:287-293

[26] M. RICHTER, D .OTTE, K. JAHANYARET et al.: Upper Extremity Fractures in Restrained Front Occupants. J Trauma. 2000;48:907-912

[27] M. RICHTER, D. OTTE, A. GANSSLEN et al.: Injuries of the pelvic ring in road traffic accidents: a medical and technical analysis. Injury. 2001;32:123-128

[28] M. RICHTER, R. FERRARI, D. OTTE et al.: Correlation of clinical findings, collision parameters, and psychological factors in the outcome of whiplash associated disorders. J Neurol Neurosurg Psychiatry. 2004;75:758-764

[29] M. RICHTER, H.C. PAPE, D. OTTE et al.: Improvements in passive car safety led to decreased injury severity – a comparison between the 1970s and 1990s. Injury. 2005; 36:484-488

[30] D. OTTE: The Accident Research Unit as Example for Importance and Benefit of Existing In-Depth Investigations. SAE Paper 940712 Detroit USA. 1994

[31] D. OTTE, C. KRETTEK, H. BRUNNER et al.: Scientific Approach and Methodology of a New In-depth Investigation Study in Germany so called GIDAS. ESV paper-, Nagoya/Japan, Mai 2003, 2003

[32] D. OTTE: 3-D-Laser Systems for scaled accident sketches and documentation of traces after accidents asa basis of biomechanical analysis. IRCOBI Conference Prague. 2005

[33] M. RICHTER, D. OTTE, U. LEHMANN et al.: Head injury mechanisms in helmet-protected motorcyclists: prospective multicenter study. J Trauma. 2001;51:949-958

[34] American Association for Automotive Medicine: Abbreviated Injury Scale – Revision 90. Am Ass F Autom Med, Morton Grove, Illinois, USA. 1995

[35] S.T. BAKER, B. O'NEILL, W. HEDDON et al.: The Injury Severity Score: A method for describing patients with multiple injuries and evaluating emergency care. J Trauma. 1974;14:187-195

[36] M. RICHTER, C. KRETTEK, D. OTTE et al.: Correlation between crash severity, injury severity, and clinical course in car occupants with thoracic trauma: a technical and medical study. J Trauma. 2001;51:10-16

[37] S. KILARU, J. GARB, T. EMHOFF et al.: Long-term functional status and mortality of elderly patients with severe closed head injuries. J Trauma. 1996;41:957-963

[38] R.M. SAYWELL, J.R. WOODS Jr., S.A. RAPPAPORT et al.: The value of age and severity as predictors of costs in geriatric head trauma patients. J Am Geriatr Soc. 1989;37:625-630

[39] M. WILLIAMS: The protective performance of bicyclists' helmets in accidents. Accid Anal Prev. 1991;23:119-131

[40] F.T. McDERMOTT: Bicyclist head injury prevention by helmets and mandatory wearing legislation in Victoria, Australia. Ann R Coll Surg Engl. 1995;77:38-44

[41] F.T. McDERMOTTT, J.C. LANE, G.A. BRAZENOR et al.: The effectiveness of bicyclist helmets: a study of 1,710 casualties. J Trauma. 1993;34:834-844

[42] F.T. McDERMOTT: Helmet efficacy in the prevention of bicyclist head injuries: Royal Australasian College of Surgeons initiatives in the introduction of compulsory safety helmet wearing in Victoria, Australia. World J Surg. 1992;16:379-383

[43] B.H. LEE, J.L. SCHOFER, F.S. KOPPELMAN: Bicycle safety helmet legislation and bicycle-related non-fatal injuries in California. Accid Anal Prev. 2005;37:93-102

[44] C. FARLEY, L. LAFLAMME, M. VAEZ: Bicycle helmet campaigns and head injuries among children. Does poverty matter? J Epidemiol Community Health. 2003;57:668-672

[45] L.F. NOVICK, M. WOJTOWYCZ, G.B. MORROW et al.: Bicycle helmet effectiveness in preventing injury and death. Am J Prev Med. 2003;24:143-149

[46] W.J. CURNOW: The efficacy of bicycle helmets against brain injury. Accid Anal Prev. 2003;35:287-292

[47] A.K. MacPHERSON, C. MacARTHUR: Bicycle helmet legislation: evidence for effectiveness. Pediatr Res. 2002;52:472

[48] D. OTTE, G. SCHROEDER, M. RICHTER: Possibilities for load reductions using garment leg protectors for motorcyclists – a technical, medical and biomechanical approach. Annu Proc Assoc Adv Automot Med. 2002;46:367-85