



Epidemiology of bicycle injuries in 13 health divisions, Islamic Republic of Iran 2003

Mohammad Karkhaneh^{a,e,*}, Mohsen Naghavi^b, Brian H. Rowe^{a,c},
Brent E. Hagel^d, Nahid Jafari^b, L. Duncan Saunders^a

^a Department of Public Health Sciences, School of Public Health, University of Alberta, Edmonton, Alberta, Canada

^b Practical Research Secretariat, Deputy Minister for Health Affairs, Ministry of Health and Medical Education,
Islamic Republic of Iran, Tehran, Iran

^c Department of Emergency Medicine, University of Alberta, Edmonton, Alberta, Canada

^d Department of Paediatrics and Community Health Sciences, Faculty of Medicine, University of Calgary, Alberta, Canada

^e Semnan University of Medical Sciences, Semnan, Iran

Received 10 August 2006; received in revised form 15 April 2007; accepted 18 May 2007

Abstract

Bicyclists are vulnerable road users for severe injury all over the world. The nature and extent of such injuries are less well known in Iran. Using data from a comprehensive survey conducted by the Ministry of Health and Medical Education in 13 health divisions of Iran, in 2003, we examined circumstances around bicyclist injury and death. Trained health workers completed the survey instruments by interviewing patients who stayed more than 24 h in hospitals and/or relatives, hospital personnel and by reviewing patient charts. Data were cross-matched with medico-legal documents to prevent missing deaths. The information that was collected from 64 cities/towns' emergency departments (EDs), over the study period, showed that 440 injured cyclists were hospitalized and/or died due to traffic collisions. Most injuries occurred in males (94.8%) and in the young (median age: 14 years with 75% $\leq$ 18 years). Head injury occurred in 14% of all hospitalized and in 90% of fatally injured bicyclists. Striking a moving vehicle increased the odds of death (OR: 32.3; 95% CI 3.5–291.0) as well as the odds of severe injury (OR: 1.9; 95% CI 1.2–3.2) compared with other mechanisms of injury. As a conclusion, bicyclists in Iran, particularly males and young children, are vulnerable to severe injury and death when struck by moving vehicles on highways.

© 2007 Elsevier Ltd. All rights reserved.

Keywords: Bicycling; Wounds and injuries; Epidemiology; Accidents traffic; Health surveys

1. Introduction

Unintentional injuries are the second leading cause of death in Iran (Naghavi, 2004). In 2000 and 2001, the rates of fatal injuries were 58.9/10⁵ persons (Naghavi, 2001) and 57/10⁵ (Naghavi, 2004), respectively. Among these the leading mechanism of death was road traffic collisions (38/10⁵) (Naghavi, 2004). In 1999, medico-legal documents (Coroner's office or Medical Examiners' documents) revealed that the crude mortality rate for road traffic collisions was 25.8/10⁵, with males demonstrating a

higher rate than females (39.1/10⁵ versus 10.5/10⁵) (Montazeri, 2004). Compared to the world estimates in 2000, traffic-related mortality in Iran was higher (31.3/10⁵ versus 19.5/10⁵) and also higher than the rate estimated for Eastern Mediterranean (EMRO)¹ countries (27.7/10⁵) (WHO, 2003). Finally, traffic collisions were also the main cause of death among children <14 in rural areas of Iran (37%) (Soori and Naghavi, 1998).

While much is known about traffic deaths and injury, the country-wide rate of bicycle injuries has not been examined in detail. Despite the importance of this problem, extensive searches for other databases revealed limited published evi-

* Corresponding author at: Department of Public Health Sciences, School of Public Health, University of Alberta, 13-103 Clinical Sciences Building, 11350-83 Avenue, Edmonton, Alberta, Canada. Tel.: +1 780 492 9228; fax: +1 780 492 7154.

E-mail addresses: mohammad.karkhaneh@ualberta.ca, Mohammad.Karkhaneh@gmail.com (M. Karkhaneh).

¹ EMRO countries include: Afghanistan, Bahrain, Djibouti, Egypt, Islamic Republic of Iran, Iraq, Jordan, Kuwait, Lebanon, Libyan Arab Jamahiriya, Morocco, Oman, Pakistan, Palestine, Qatar, Saudi Arabia, Somalia, Sudan, Syrian Arab Republic, Tunisia, United Arab Emirates, Yemen.

dence. A 1-year study in an Iranian province in 1999 revealed that 4.9% of injured children in urban and sub-urban areas referred to emergency departments were pedal cyclists, of whom, 55% had head injuries (Soori, 2002). In another provincial study in 1994, of 2304 traffic-related injuries which referred to ED, 191 (8.2%) were in bicyclists and 37 (21%) of these suffered from head injuries (representing 6.7% of all traffic-related head injuries) (Foroudnia and Janghorbani, 1996).

The rate and severity of bicycle injuries has decreased in many countries in the past 25 years (Nixon et al., 1987; Cushman et al., 1992; Vulcan et al., 1992; Thompson et al., 1995; Linn et al., 1998; Wesson et al., 2000; Cook and Sheikh, 2003). To prevent cycling casualties, methods of protection such as bicycle helmets (Lardelli et al., 2003), designated cycling paths, (Staunton et al., 2003; Boarnet et al., 2005) and visibility aids (Kwan and Mapstone, 2004) have been employed. Some jurisdictions have also introduced social interventions such as helmet legislation, (Cameron et al., 1994; Macknin and Medendorp, 1994; Ni et al., 1997; Kanny et al., 2001; Lee et al., 2005) and promotional programs (Dannenberg et al., 1993; Rivara et al., 1994; Abularrage et al., 1997; Farley et al., 2003) to increase helmet use. Conversely, many countries, such as Iran, have not implemented any of these efforts to reduce bicycling injuries.

Given the various and practical interventions for injury prevention, it is important to explore the causes of cycling injuries in Iran in order to prioritize interventions. The current study was designed to examine the circumstances and nature of cycling injuries in 13 health divisions in Iran and describe the risk factors for serious injuries.

2. Method

2.1. Data procedure

This is a secondary analysis of a data set provided by the Ministry of Health and Medical Education of the Islamic Republic of Iran. Permission to use this data-set was provided by the Deputy Minister for Health Affairs (Dr. M.E. Akbari). The Health Research Ethics Board at the University of Alberta also approved this analysis.

In 2003, a comprehensive survey, addressing ten categories of injuries including traffic-related injuries, was conducted in 13 health divisions located in 11 provinces of Iran (population 9,817,797) by Naghavi and colleagues. Standard data collection instruments were completed by trained nurses and health workers in all hospitals located in 64 cities/towns. These research assistants interviewed patients who stayed more than 24 h in hospital or their relatives (if patient was too sick or had died) and hospital personnel and also extracted clinical data from emergency department and hospital records. They also supplemented fatalities with information from medico-legal documents (Coroner or Medical Examiners' documents) to prevent any missing cases. For each health division, depending on the prevalence of injuries in the previous years, data collection period was scheduled for 3–6 months. This report will focus on the data coded as bicycle injuries from the category of motor vehicle injuries.

2.2. Instruments

The survey instrument consisted of two main parts; the first part included demographic information, time, location, mechanism of injury and outcome, and the second part employed the ICD-9 N code system describing the type of injury observed (Appendix A). We calculated the Abbreviated Injury Scale (AIS) (Association for the Advancement of Automotive Medicine, 1990) and Injury Severity Score (ISS) (Baker, 1974) for each individual. We also categorized injuries by body region (Barell et al., 2002). We assigned $ISS \leq 8$ and $ISS > 8$ as the cut point for low and high severity of injury to perform univariate and multivariate analyses (Rivara et al., 1997).

2.3. Reliability sub-study

To assess reliability, a sub-study was performed on 26 charts including all 6 bicyclists and a random sample of 20 motorcyclists from a trauma center in Semnan city (center of Semnan health division) by one of the authors (MK). We compared data from the original survey instruments with the new completed instrument by the assessor, using patients' charts (no interviews were performed). Simple agreement (%) between two records was examined and reported.

2.4. Analysis

Using SPSS software (SPSS Inc., 2004), initial analyses described the characteristics of the population and the type and anatomical distribution of injuries. Because the length of data collection varied between 3 and 6 months among different health regions; for examining risk of casualties among health divisions, we assumed a Poisson distribution for injury occurrence, adjusted by person-time of exposure, to estimate rate ratios (RR) and 95% CI. Univariate analysis assessed associations between severity of injury or death and important factors like age, sex, residence, mechanism and location of injury. Due to insufficient numbers of death in some subgroups (Table 1), we used indicator variables to predict the risk of each mechanism or location.

Unconditional logistic regression was used to calculate odds ratios (and 95% confidence intervals (CI)) adjusted for selected covariates that were statistically significant at the 0.10 level in univariate analysis. Age and sex were included in all regression models for substantive reasons (Acton et al., 1995; Bostrom and Nilsson, 2001).

3. Results

3.1. Reliability results

Of the 26 hospitalized patients, 8 died. Simple agreement was excellent for the following categories: age, sex, residence, education (all 100%), injury sustained in cases that died ($n=8$; 100%), location of collisions (96%), and rider/passenger status (85%). Agreement was lower for the exact injury sustained in those surviving their injuries (66%). Disagreements were minor and did not influence the ISS scoring.

Table 1
Number of injured cyclists by circumstances

	Died	Injured	Total
Mechanism of collision			
Falling to the ground	1 (5.0) ^a	232 (55.2)	233 (53.0)
Striking a fixed object	0 (0.0)	27 (6.4)	27 (6.1)
Striking a moving vehicle	19 (10.7)	159 (37.9)	178 (40.0)
Being hit by other vehicles	0 (0.0)	2 (0.5)	2 (0.5)
Total	20 (100.0)	420 (100.0)	440 (100.0)
Education			
No education	4 (20.0)	52 (12.4)	56 (12.7)
Primary school	6 (30.0)	167 (39.8)	173 (39.3)
Middle school	7 (35.0)	112 (26.7)	119 (27.0)
High school	2 (10.0)	49 (11.7)	51 (11.6)
University	0 (0.0)	21 (5.0)	21 (4.8)
Graduate	0 (0.0)	5 (1.2)	5 (1.1)
Others	1 (5.0)	14 (3.3)	15 (3.4)
Total	20 (100.0)	420 (100.0)	440 (100.0)
Delivery method			
EMS	3 (25.0)	25 (6.0)	28 (6.5)
Police	0 (0.0)	4 (1.0)	4 (0.9)
Bystanders	9 (75.0)	369 (88.7)	378 (88.3)
Self-rescued	0 (0.0)	18 (4.3)	18 (4.2)
Total	12 (100.0)	416 (100.0)	428 (100.0)
Time of collisions			
1:00 a.m. to 7:00 a.m.	2 (10.0)	5 (1.2)	7 (1.6)
7:00 a.m. to 1:00 p.m.	10 (50.0)	118 (28.4)	128 (29.4)
1:00 p.m. to 7:00 p.m.	7 (35.0)	202 (48.7)	209 (48.0)
7:00 p.m. to 1:00 a.m.	1 (5.0)	90 (21.7)	91 (20.9)
Total	20 (100.0)	415 (100.0)	435 (100.0)
Location of collisions			
Street or alley	7 (35.0)	331 (78.8)	338 (76.8)
Highway	0 (0.0)	8 (1.9)	8 (1.8)
Inter-city highway	5 (25.0)	15 (3.6)	20 (4.5)
Inter-city express way	4 (20.0)	5 (1.2)	9 (2.0)
Rural road	4 (20.0)	52 (12.4)	56 (12.7)
Yard of house or school	0 (0.0)	9 (2.1)	9 (2.0)
Total	20 (100.0)	420 (100.0)	440 (100.0)

^a Percentage within columns.

3.2. Study sample

During the study period in 13 health divisions, 8817 persons were hospitalized and/or died due to traffic-related injuries: 440 (5%) of whom were pedal cyclists including 20 (4.5%) who died.

3.3. Study population

The majority of pedal cyclists involved in a crash were male (94.8%) with a median age of 14 years (75% ≤18). Overall, 68.2% of them lived in urban areas and 6.8% were companion to bicycle riders. The level of education of crashed bicyclists was different among which 12.7% had no education, 66.7% had completed primary and middle school, and 5.9% were graduates of colleges or universities. The risk of cycling injury varied among 13 health divisions; four of which revealed a higher risk of injury than the overall population (Table 2). Due to an absence of deaths in some regions, analyses of death could not be completed for all health regions. One region (Kashan) had a significantly higher

risk of death compared with the overall population (RR: 7.36; 95% CI: 2.51–21.53) (Table 2).

Examining age, sex and residence of injured cyclists in all health regions revealed that the 5–14 year olds had the highest incidence rate of bicycling injuries at 25.0/100,000 person-years (p-ys), which is 3–4 times greater than that in other age groups. The incidence rate of injury among males (18.5/100,000 p-ys) was 17 times greater than females (1.1/100,000 p-ys) and the incidence rate of injury in urban areas (11.8/100,000 p-ys) was 45% greater than rural areas (8.1/100,000 p-ys) (Table 3).

3.4. Injuries sustained

Approximately 73% (307) of injured bicyclists (non-fatal) sustained one injury, 22% (94) had two injuries and 5% (19) had three injuries. External injuries, including open wounds and crush injuries, were the most common (30%). Upper (25%) and lower extremities (20%) were the next most common injuries. Head injuries, including skull fractures and brain injuries, comprised 14% (63) of cycling injuries. Overall, 62% of crashed

Table 2
Rate ratio (RR) of cycling injury and death in 13 health divisions, Iran 2003

Health divisions	Period data collected (month)	Population	Person month of exposure	Number of injury	Expected no. of injury adj. for time period	RR of injury	95% CI	Number of death	Expected no. of death adj. for time period	RR of death	95% CI
Charmahal-B	3.3	844,256	2786044.8	76	32.8	2.31*	1.85, 2.90	2	1.6	1.28	0.32, 5.12
Arak	4.3	1,290,257	5548105.1	24	65.4	0.37*	0.25, 0.55	1	3.1	0.32	0.04, 2.28
Hamadan	4	1,729,663	6,918,652	106	81.5	1.30*	1.07, 1.57	3	3.8	0.77	0.25, 2.40
Yazd	4.3	895,167	3849218.1	43	45.3	0.95	0.70, 1.27	0	2.1	–	No death
Kermanshah	3.2	1,876,818	6005817.6	35	70.7	0.49*	0.35, 0.69	5	3.4	1.48	0.62, 3.56
Zanjan	3.5	961,519	3365316.5	43	39.6	1.08	0.80, 1.46	0	1.9	–	No death
Booshehr	3.5	779,306	2,727,571	14	32.1	0.43*	0.26, 0.73	3	1.5	1.96	0.63, 6.08
Semnan	2.5	311,741	779352.5	10	9.2	1.09	0.59, 2.02	0	0.4	–	No death
Kashan	3.8	254,974	968901.2	19	11.4	1.66*	1.06, 2.61	4	0.5	7.36*	2.76, 19.61
Fasa	3.8	206,836	785976.8	11	9.2	1.18	0.66, 2.14	1	0.4	2.27	0.32, 16.10
Jahrom	2.7	192,899	520827.3	8	6.1	1.30	0.65, 2.61	1	0.3	3.2	0.48 24.30
Rafsanjan	2	250,820	501,640	6	5.9	1.01	0.46, 2.26	0	0.3	–	No death
Shahrood	4	223,564	894,256	25	10.5	2.37*	1.60, 3.51	0	0.5	–	No death
Total (reference)		9,817,820	35651678.9	420	~420	1.00	–	20	~20	1.00	–

Example for the first health region (Charmahal-B): $3.3 \times 844,256 = 2786044.8$ person month of exposure; expected number of injuries for 3.3 months = $(420(\text{total injured})/35651678.9) \times 2786044.8 = 32.8$. Using formula: estimated RR for injury or death = observed/expected; 95% CI = $\text{EXP}[\text{LN}(\text{RR}) \pm 1.96 \times \text{SQRT}(1/\text{observed})]$; estimated RR $76/32.8 = 2.31$ then 95% CI = $\text{EXP}[\text{LN}(2.31) \pm 1.96 \times \text{SQRT}(1/76)]$ is (1.85, 2.90).

* Statistically significant.

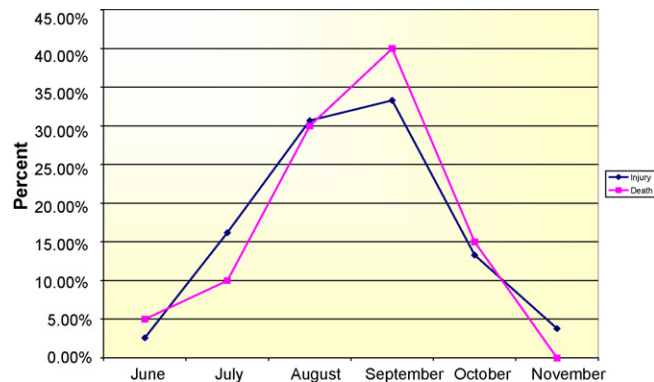


Fig. 1. Percentage of bicyclists' casualties by months among 13 health divisions, Iran 2003.

bicyclists had at least one injury of the upper or lower extremities and 47% sustained external or superficial injuries. While pedal cyclists under age 20 were more likely to experience extremity injuries (OR: 1.5; 95% CI: 0.92–2.5), bicyclists over 54 years were more likely to suffer from head injuries (OR: 3.6; 95% CI: 1.7–7.5) and chest/abdomen injuries (OR: 6.0; 95% CI: 2.1–17.0). External injuries did not show any particular pattern among age groups.

3.5. Death events

Most deaths were due to head injuries (18/20, 90%). The two remaining deaths were caused by a spinal cord injury and a heart attack. Of the bicyclists who died, 8 (40%) died at the scene of collision, 3 (15%) during transportation and 9 (45%) at the hospital. More information about the mechanism, time, and location of collisions, education and rescue method is provided in Table 1. Cycling injuries and deaths seemed to follow a seasonal pattern. As the weather warmed (e.g., the beginning of the spring to the mid-summer), cycling injuries increased, peaking in September, and then declined through to November (Fig. 1).

3.6. Univariate analyses

Pedal cyclists who struck a moving vehicle were two times more likely to suffer a severe injury (OR: 2.0; 95% CI 1.27–3.1) than other mechanisms of injury (e.g. fall, striking a stationary object or being hit by a vehicle). Compared with other mechanism of injuries, falling from bicycle was accompanied by a lower risk of severe injury (OR: 0.54; 95% CI 0.3–0.8). Individuals within 6–12, 13–17, and 18–54 age groups demonstrated a lower risk of severe injury than those 55 years and older (OR: 0.36; 95% CI 0.2–0.7), (OR: 0.27; 95% CI 0.1–0.6) and (OR: 0.41; 95% CI 0.2–0.9), respectively. Sex, residence, time, location of collision, and companionship (being a passenger on a bicycle) did not influence the severity of injuries (Table 4).

Striking a moving vehicle significantly increased the risk of death (OR: 31.2; 95% CI 4.1–235.0) compared with other mechanisms of injury (e.g. fall, striking a stationary object or being hit by a vehicle). Other significant risk factors for death were those

Table 3

Incidence of fatal and non-fatal injuries (per 100,000 person years) in total population of 13 health divisions; based on age, sex and residence

Age groups	Male			Female			Total		
	Urban	Rural	Total	Urban	Rural	Total	Urban	Rural	Total
<5 years	8 ^a (8.3) ^b	4 (7.0)	12 (7.8)	2 (2.2)	2 (3.6)	4 (2.7)	10 (5.3)	6 (5.3)	16 (5.3)
5–14	143 (50.2)	74 (37.5)	217 (45.0)	12 (4.4)	6 (3.1)	18 (3.9)	155 (28.0)	80 (20.7)	235 (25.0)
15–49	100 (13.2)	44 (10.1)	144 (12.0)	1 (0.1)	0 (0.0)	1 (0.1)	101 (6.7)	44 (5.2)	145 (6.1)
≥50	34 (23.5)	10 (3.5)	44 (10.3.5)	0 (0.0)	0 (0.0)	0 (0.0)	34 (12.0)	10 (2.5)	44 (6.5)
Total	285 (22.2)	132 (13.5)	417 (18.5)	15 (1.2)	8 (1.0)	23 (1.1)	300 (11.8)	140 (8.1)	440 (10.35)

^a Actual frequency of injured cyclists.^b Incidence.

collisions occurring on highways (OR: 11.4; 95% CI 4.3–29.9) compared with other locations including streets or alleys, rural roads and house or school yards. Collisions occurred between 1:00 a.m. and 1:00 p.m. caused more death (OR: 3.6; 95% CI 1.4–8.9) than those happened after 1.00 p.m. up to 1.00 a.m. Age, sex, residence, falling into the ground and being a passenger did not introduce any additional risk of death (Table 4).

3.7. Multivariate analysis

In the multivariate model, severe injury was associated with striking a moving vehicle (OR = 1.97; 95% CI: 1.2–3.2) and inversely associated with age 6–12 (OR = 0.40; 95% CI: 0.2–0.84). The Hosmer Lemeshow goodness of fit test indicated that there were no problems with the model fit for both models. (p -value = 0.99). We did not fit a multivariate model for fatal injuries due to the small number of outcomes.

4. Discussion

This prospective study examined traffic-related injuries resulting in hospitalization or death in 13 health divisions in Iran. Of the total number of traffic-related injuries (8817) in this study, 5% (440) were in bicyclists. This proportion was similar to two previous smaller provincial studies in Iran (Foroudnia and Janghorbani, 1996; Soori, 2002), and also comparable to proportions in other countries (Kennedy, 1996; Jacobson et al., 1998; Klimentopoulou et al., 2004). The male/female ratio of 17:1 is similar to that found in another study performed in 6 university hospitals in Tehran with 13.4:1 (Roudsari et al., 2004); however, it is larger than results in Ahvaz and Kerman; 3.7 and 4.6 (Foroudnia and Janghorbani, 1996; Soori, 2002), respectively.

In other countries, male/female ratios varied between 1 and 4 (Cushman et al., 1990; Frank et al., 1995; Foltin, 1996; McCarthy and Gilbert, 1996; Otero et al., 1997; Rivara et al.,

Table 4

Univariate analysis: severity of injuries and fatality by main attributes of cyclists and indicators of collisions

	% ISS > 8 ($n = 103$; 24.5%)	% ISS ≤ 8 ($n = 317$; 75.5%)	OR	95% CI	% Dead ($n = 20$; 4.5%)	% Injured ($n = 420$; 95.5%)	OR	95% CI
Age (in year)								
≤5	4.9	3.5	0.53	0.1–1.8	0.0	3.8	–	–
6–12	35.0	37.2	0.36*	0.1–0.7	15.0	36.7	0.24	0.05–1.2
13–17	27.2	37.5	0.27*	0.1–0.6	45.0	35.0	0.75	0.2–2.9
18–54	16.5	15.5	0.41*	0.2–0.9	25.0	15.7	0.93	0.2–4.1
≥55	16.5	6.3	1.00	Reference	15.0	8.8	1.00	Reference
Gender								
Male	93.2	95.3	1.00	Reference	95.0	94.8	1.00	Reference
Female	6.8	4.7	1.47	0.6–3.7	5.0	5.2	0.95	0.1–7.4
Residence								
Urban	74.8	67.2	1.00	Reference	50.0	69.0	1.00	Reference
Rural	25.5	32.8	0.7	0.4–1.1	50.0	31.0	2.23	0.9–5.4
Fall ^a (other mechanisms) ^b	43.7	59.0	0.54*	0.3–0.8	5.0	55.2	0.04	0.01–0.3
Passenger of bicycle (rider)	10.7	6.0	1.9	0.9–4.0	0.0	7.1	–	–
Striking a moving vehicle (other mechanisms)	50.5	33.8	2.00*	1.27–3.1	95.0	37.9	31.2*	4.1–235.0
Time (PM)	29.4	29.7	0.98	0.6–1.6	60.0	29.6	3.6*	1.4–8.9
Highway collision (other locations)	8.7	6.0	1.50	0.6–3.4	45.0	6.7	11.4*	4.3–29.9

^a Indicator variable.^b Reference.

* Statistically significant.

1997; Linn et al., 1998; Bostrom and Nilsson, 2001; Davidson, 2005). The reason why fewer females were injured than males in this survey might be due to social customs in Iran which discourage females from riding in public places; however, we cannot prove this scientifically. Alternative explanations include that women tend to be more cautious (Soori, 1999) and also ride more slowly than males (Graitcer et al., 1995).

The majority of injured bicyclists (75%) were ≤ 18 years, with a median age of 14 which was similar to a report by Frank et al (60% were < 21) in Oregon (Frank et al., 1995) and Stutts et al. (62% were 5–14) in North Carolina, USA (Stutts et al., 1990). In our study the 5–14 age group had the highest incidence rate of cycling injuries (25.0 per 100,000 p-ys): this was approximately 4 times greater than bicyclists < 5 , 15–49, and ≥ 50 years of age. We do not know the cycling behavior of each age group; however, higher incidence of injuries among 5–14 age-groups may reflect a greater cycling exposure. Lack of experience and greater risk taking behavior (Everett et al., 2001) might be other factors that influence injury rates among different ages.

The incidence rate of injury in urban areas (11.8/100,000 p-ys) was 45% greater than rural areas (8.1/100,000 p-ys). No further information was available to explain this finding, however, difference in exposures, road conditions and safety habits could partially explain that (Macpherson et al., 2004).

An important finding in our study was information about head trauma among bicyclists who crashed. We found that one-quarter of injured bicyclists had severe injuries (24.5% with ISS > 8) mainly involving head trauma, which contributed to 18 out of 20 deaths. This finding is similar to other studies indicating that brain injury is a leading cause of death (Sacks et al., 1991; Acton et al., 1995; Kennedy, 1996; McCarthy and Gilbert, 1996; Li and Baker, 1997; Montazeri, 2004) among pedal cyclists.

Although there was no information about helmet use, we assume few bicyclists were wearing helmets. This assumption is based on findings from three studies in Iran, where none of the injured bicyclists referred to hospitals were using a bicycle helmet at the time of collision (Foroudnia and Janghorbani, 1996; Soori, 2002; Zargar et al., 2004). While bicycle helmets are highly effective at preventing mild and severe head injuries (Maimaris et al., 1994; Thomas et al., 1994; Grimard et al., 1995; Kennedy, 1996; Jacobson et al., 1998; Linn et al., 1998; Thompson et al., 1999), at the present time there is no legislation mandating bicycle helmet use in Iran.

We found that bystanders delivered most injured bicyclists to hospital (88% among injured, 75% among dead bicyclists). As emergency medical services (EMS) usually apply standardized methods of treating and mobilizing injured patients, it seems reasonable to attempt to increase the number of injured cyclists assessed and transported by EMS in Iran. A study examining the efficiency of the EMS system in Tehran showed that the mean time interval for “dispatch-beginning to hospital-arrival” was 45 min (Modaghegh et al., 2002), which is greater than what reported for EMS in Seattle, (Arreola-Risa et al., 1995) or in Orana, New South Wales, Australia (Papadimitriou et al., 1994), and in Helicopter EMS (Biewener et al., 2005). We also found that some regions experienced higher rates of injury than others (e.g. Kashan, Shahrood); however, further detailed infor-

mation about riding exposure is required before more definitive conclusions can be drawn.

There are some limitations for this study. This survey was restricted to those injured bicyclists who were hospitalized for more than 24 h. Because many minor injuries may be assessed and treated in an emergency setting without requiring admission, the actual number of cycling injuries might have been underestimated in this study (Cushman et al., 1990; Linn et al., 1998; Dennerlein and Meeker, 2002; Davidson, 2005). It is likely, however, that we captured most of the severe cycling injuries in this study.

Different time frame of data collection for each health division may have introduced a limitation for this study; however, by collecting all data in spring-summer and application of person-time of exposure, we accounted for the difference in periods of data collection and seasonal effect. We did not control for differences due to temporal variations within spring-summer months.

Since the reliability sub-study had a small sample size, findings cannot be considered conclusive; however, we noted high agreement (85–100%) between coders, except for the type of injury sustained among survivors (66%).

Notwithstanding these concerns, this survey is a geographically extended cross-sectional study of bicycle injuries in Iran and an analytic epidemiologic study on important risk factors. This kind of investigation has not been performed among the Iranian population before and it highlights the public health importance of similar investigations in other international locations.

5. Conclusion

From this evaluation two conclusions can be made:

1. Bicyclists, particularly males and young children in Iran are vulnerable to severe injury and death. The risk of serious injury or death is higher when the mechanism of injury is striking a moving vehicle on a highway.
2. The head is the most frequent site of severe injury with or without subsequent death.

More population-based studies are needed to explore the actual number of injured pedal cyclists presenting to the EDs, including those with minor injuries. Information from the scene of collisions and an assessment of the cycling habits and use of bicycle helmets in Iran can add to our current knowledge. A clear picture of circumstances surrounding pedal cyclists will provide information for policy makers and other stakeholders to employ new measures to prevent such severe injuries and deaths.

Acknowledgements

The authors wish to thank an anonymous reviewer for his/her recommendations. The authors would also like to thank Dr. Ali Rashidy-pour and Dr. Mohammad Forozesh-fard for providing access to patients charts in Amir-al-Momenin hospital in Semnan. Dr. Karkhaneh's PHD training is supported by the Gov-

ernment of Iran and Semnan University of Medical Sciences. Dr. Rowe is supported by the Government of Canada through the 21st Century Canada Research Chair Program. Dr. Hagel holds the recently appointed position of Professorship in Child Health and Wellness funded by the Alberta Children's Hospital Foundation, through the support of an anonymous donor and the Canadian National Railway Company.

Appendix A. Global burden of diseases classification for ICD-9 nature of injury

Nature of injury	ICD-9 N code
1 Fracture skull	800–801
2 Fractured face bone	802
3 Fractured vertebral column	805
4 Injured spinal cord	806 and 952
5 Fractured rib or sternum	807
6 Fractured pelvis	808
7 Fractured clavicle, scapula, or humerus	810–812
8 Fractured radius or ulna	813
9 Fractured hand bones	814–817
10 Fractured femur	820–821
11 Fractured patella, tibia, or fibula	822–823
12 Fractured ankle	824
13 Fractured foot bones	825–826
14 Other dislocation	830, 833–834, 836–839
15 Dislocation shoulder, elbow, or hip	831, 832, 835
16 Sprains	840–848
17 Intracranial injury	850–8554
18 Internal injuries	860–869
19 Open wound	870, 872–884, 890–894
20 Injury to eyes	871, 950
21 Amputated thumb	885
22 Amputated finger	886
23 Amputated arm	887
24 Amputated toe	895
25 Amputated foot	896, 897.0–897.1
26 Amputated leg	897.2–897.3
27 Crushing	925–929
28 Burns <20%	940–947, 948.0–948.1
29 Burns >20% and <60%	948.2–948.5
30 Burns >60%	948.6–948.9
31 Injured nerves	951, 953–957
32 Poisoning	960–979, 980–989

References

Abularrage, J.J., DeLuca, A.J., Abularrage, C.J., 1997. Effect of education and legislation on bicycle helmet use in a multiracial population. *Arch. Pediatr. Adolesc. Med.* 151 (1), 41–44.

Acton, C.H., Thomas, S., Nixon, J.W., Clark, R., Pitt, W.R., Battistutta, D., 1995. Children and bicycles: what is really happening? Studies of fatal and non-fatal bicycle injury. *Injury Prev.* 1 (2), 86–91.

Arreola-Risa, C., Mock, C.N., Padilla, D., Cavazos, L., Maier, R.V., Jurkovich, G.J., 1995. Trauma Care Systems in Urban Latin America: the priorities should be prehospital and emergency room management. *J. Trauma-Injury Infect. Crit. Care* 39 (3), 457–462.

Association for the Advancement of Automotive Medicine. The Abbreviated Injury Scale, Des Plaines, IL: AAAM 1990 revision (updated 98), USA.

Baker, S.P., 1974. The injury severity scores: a method for describing patients with multiple injuries and evaluating emergency care. *J. Trauma-Injury Infect. Crit. Care* 14, 187–196.

Barell, V., Aharonson-Daniel, L., Fingerhut, L.A., Mackenzie, E.J., Ziv, A., Boyko, V., Abargel, A., Avitour, M., Heruti, R., 2002. An introduction to the Barell body region by nature of injury diagnosis matrix. *Injury Prev.* 8 (2), 91–96.

Biewener, A., Aschenbrenner, U., Sauerland, S., Zwipp, H., Rammelt, S., Sturm, J., Ag Notfallmedizin, D.G.U., 2005. Impact of rescue method and the destination clinic on mortality in polytrauma. A status report. *Unfallchirurg* 108 (5), 370–377.

Boarnet, M.G., Anderson, C.L., Day, K., Mcmillan, T., Alfonso, M., 2005. Evaluation of the California Safe Routes to School legislation: urban form changes and children's active transportation to school. *Am. J. Prev. Med.* 28 (2 Suppl. 2), 134–140.

Bostrom, L., Nilsson, B., 2001. A review of serious injuries and deaths from bicycle accidents in Sweden from 1987 to 1994. *J. Trauma-Injury Infect. Crit. Care* 50 (5), 900–907.

Cameron, M.H., Vulcan, A.P., Finch, C.F., Newstead, S.V., 1994. Mandatory bicycle helmet use following a decade of helmet promotion in Victoria, Australia—an evaluation. *Accid. Anal. Prev.* 26 (3), 325–337.

Cook, A., Sheikh, A., 2003. Trends in serious head injuries among English cyclists and pedestrians. *Injury Prev.* 9 (3), 266–267.

Cushman, R., Down, J., Macmillan, N., Wacławik, H., 1990. Bicycle-related injuries: a survey in a pediatric emergency department. *Can. Med. Assoc. J.* 143 (2), 108–112.

Cushman, R., Pless, R., Hope, D., Jenkins, C., 1992. Trends in bicycle helmet use in Ottawa from 1988 to 1991. *Can. Med. Assoc. J.* 146 (9), 1581–1585.

Dannenberg, A.L., Gielen, A., Beilenson, P.L., Wilson, M.H., Joffe, A., 1993. Bicycle helmet laws and educational campaigns: an evaluation of strategies to increase children's helmet use. *Am. J. Public Health* 83 (5), 667–674.

Davidson, J.A., 2005. Epidemiology and outcome of bicycle injuries presenting to an emergency department in the United Kingdom. *Eur. J. Emerg. Med.* 12 (1), 24–29.

Dennerlein, J.T., Meeker, J.D., 2002. Occupational injuries among Boston bicycle messengers. *Am. J. Ind. Med.* 42 (6), 519–525.

Everett, S.A., Shults, R.A., Barrios, L.C., Sacks, J.J., Lowry, R., Oeltmann, J., 2001. Trends and subgroup differences in transportation-related injury risk and safety behaviors among high school students, 1991–1997. *J. Adolesc. Health* 28 (3), 228–234.

Farley, C., Laflamme, L., Vaez, M., 2003. Bicycle helmet campaigns and head injuries among children. Does poverty matter? *J. Epidemiol. Commun. Health* 57 (9), 668–672.

Foltin, E., 1996. Pediatric and adolescent accident victims (ICD-E 800 to 829) in Austria 1980 to 1989. *Unfallchirurgie* 22 (3), 99–109.

Foroudnia, F., Janghorbani, M., 1996. Characteristics of the inner city road traffic casualties in Kerman during 1994 (in Persian). *J. Kerman Univ. Med. Sci.* Iran 3 (1), 35–42.

Frank, E., Frankel, P., Mullins, R.J., Taylor, N., 1995. Injuries resulting from bicycle collisions. *Acad. Emerg. Med.* 2 (3), 200–203.

Graitcer, P.L., Kellermann, A.L., Christoffel, T., 1995. A review of educational and legislative strategies to promote bicycle helmets. *Injury Prev.* 1 (2), 122–129.

Grimard, G., Nolan, T., Carlin, J.B., 1995. Head injuries in helmeted child bicyclists. *Injury Prev.* 1 (1), 21–25.

Jacobson, G.A., Blizzard, L., Dwyer, T., 1998. Bicycle injuries: road trauma is not the only concern. *Aust. N. Z. J. Public Health* 22 (4), 451–455.

Kanny, D., Schieber, R.A., Pryor, V., Kresnow, M.J., 2001. Effectiveness of a state law mandating use of bicycle helmets among children: an observational evaluation. *Am. J. Epidemiol.* 154 (11), 1072–1076.

Kennedy, A., 1996. The pattern of injury in fatal pedal cycle accidents and the possible benefits of cycle helmets. *Br. J. Sports Med.* 30 (2), 130–133.

Klimentopoulou, A., Paliokosta, E., Towner, E., Petridou, E., 2004. Bicycling-related injuries among children in Greece. *Eur. J. Trauma* 30 (3), 182–186.

Kwan, I., Mapstone, J., 2004. Visibility aids for pedestrians and cyclists: a systematic review of randomised controlled trials. *Accid. Anal. Prev.* 36 (3), 305–312.

Lardelli, C.P., Luna del, C., et al., 2003. An assessment of the effect of helmet use among cyclists and the risk of head injury and death in Spain, 1990 to 1999. *Med. Clin.* 120 (3), 85–88.

- Lee, B.H., Schofer, J.L., Koppelman, F.S., 2005. Bicycle safety helmet legislation and bicycle-related non-fatal injuries in California. *Accid. Anal. Prev.* 37 (1), 93–102.
- Li, G., Baker, S.P., 1997. Injuries to bicyclists in Wuhan, People's Republic of China. *Am. J. Public Health* 87 (6), 1049–1052.
- Linn, S., Smith, D., Sheps, S., 1998. 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)*. *Injury Prev.* 4 (2), 122–125.
- Macknin, M.L., Medendorp, S.V., 1994. Association between bicycle helmet legislation, bicycle safety education, and use of bicycle helmets in children. *Arch. Pediatr. Adolesc. Med.* 148 (3), 255–259.
- Macpherson, A.K., To, T.M., Parkin, P.C., Moldofsky, B., Wright, J.G., Chipman, M.L., Macarther, C., 2004. Urban/rural variation in children's bicycle-related injuries. *Accid. Anal. Prev.* 36 (4), 649–654.
- Maimaris, C., Summers, C.L., Browning, C., Palmer, C.R., 1994. Injury patterns in cyclists attending an accident and emergency department: a comparison of helmet wearers and non-wearers. *Br. Med. J.* 308 (6943), 1537–1540.
- McCarthy, M., Gilbert, K., 1996. Cyclist road deaths in London 1985–1992: drivers, vehicles, maneuvers and injuries. *Accid. Anal. Prev.* 28 (2), 275–279.
- Modaghegh, M.H., Roudsari, S.B., Sajadehchi, A., 2002. Pre-hospital trauma care in Tehran: potential areas for improvement. *Pre-hosp. Emerg. Care* 6 (2), 218–223.
- Montazeri, A., 2004. Road-traffic-related mortality in Iran: a descriptive study. *Public Health* 118 (2), 110–113.
- Naghavi, M., 2001. Causes of Death in 10 Provinces of Iran in 2001 (in Persian). Published by the Ministry of Health and Medical Education and WHO agent, Tehran, Iran.
- Naghavi, M., 2004. Epidemiology of external causes of injury in the Islamic Republic of Iran 2002 (in Persian). Published by the Ministry of Health and Medical Education, Tehran, Iran.
- Ni, H., Sacks, J.J., Curtis, L., Cieslak, P.R., Hedberg, K., 1997. Evaluation of a statewide bicycle helmet law via multiple measures of helmet use. *Arch. Pediatr. Adolesc. Med.* 151 (1), 59–65.
- Nixon, J., Clacher, R., Pearn, J., Cocoran, A., 1987. Bicycle accidents in childhood. *Br. Med. J.* 294 (6582), 1267–1269.
- Odero, W., Garner, P., Zwi, A., 1997. Road traffic injuries in developing countries: a comprehensive review of epidemiological studies. *Trop. Med. Int. Health* 2 (5), 445–460.
- Papadimitriou, D.G., Mathur, M.N., Hill, D.A., 1994. A survey of rural road fatalities. *Aust. N. Z. J. Surg.* 64 (7), 479–483.
- Rivara, F.P., Thompson, D.C., Thompson, R.S., 1997. Epidemiology of bicycle injuries and risk factors for serious injury. *Injury Prev.* 3 (2), 110–114.
- Rivara, F.P., Thompson, D.C., Thompson, R.S., Rogers, L.W., Alexander, B., Felix, D., Bergman, A.B., 1994. The Seattle children's bicycle helmet campaign: changes in helmet use and head injury admissions. *Pediatrics* 93 (4), 567–569.
- Roudsari, B.S., Sharzei, K., Zargar, M., 2004. Sex and age distribution in transport-related injuries in Tehran. *Accid. Anal. Prev.* 36 (3), 391–398.
- Sacks, J.J., Holmgreen, P., Smith, S.M., Sosin, D.M., 1991. Bicycle-associated head injuries and deaths in the United States from 1984 through 1988. How many are preventable? [see comment]. *J. Am. Med. Assoc.* 266 (21), 3016–3018.
- Soori, H., 1999. Children's risky activities and parents' ideas on children's risk taking behavior. *Med. J. Islamic Republic Iran* 13 (1), 19–26.
- Soori, H., 2002. Epidemiology of children's cycling injuries in Ahwaz, Islamic Republic of Iran. *East. Mediterr. Health J.* 8 (2/3), 308–314.
- Soori, H., Naghavi, M., 1998. Childhood deaths from unintentional injuries in rural areas of Iran. *Injury Prev.* 4 (3), 222–224.
- SPSS 13 for Windows, 2004. Copyright (c) SPSS Inc. Chicago, IL 60606-6307, USA.
- Staunton, C.E., Hubsmith, D., Kallins, W., 2003. Promoting safe walking and biking to school: the Marin County success story. *Am. J. Public Health* 93 (9), 1431–1434.
- Stutts, J.C., Williamson, J.E., Whitley, T., Sheldon, F.C., 1990. Bicycle accidents and injuries: a pilot study comparing hospital-and police-reported data. *Accid. Anal. Prev.* 22 (1), 67–78.
- Thomas, S., Acton, C., Nixon, J., Battistutta, D., Pitt, W.R., Clark, R., 1994. Effectiveness of bicycle helmets in preventing head injury in children: case-control study. *Br. Med. J.* 308 (6922), 173–176.
- Thompson, D.C., Rivara, F.P., Thompson, R.S., 1999. Helmet for preventing head and facial injuries in bicyclists. *Cochrane Database Syst. Rev.* (2), doi:10.1002/14651858.CD001855.
- Thompson, R.S., Taplin, S.H., McAfee, T.A., Mandelson, M.T., Smith, A.E., 1995. Primary and secondary prevention services in clinical practice. Twenty years' experience in development, implementation, and evaluation. *J. Am. Med. Assoc.* 273 (14), 1130–1135.
- Vulcan, A.P., Cameron, M.H., Watson, W.L., 1992. Mandatory bicycle helmet use: experience in Victoria, Australia. *World J. Surg.* 16 (3), 389–397.
- Wesson, D., Spence, L., Hu, X., Parkin, P., 2000. Trends in bicycling-related head injuries in children after implementation of a community-based bike helmet campaign. *J. Pediatr. Surg.* 35 (5), 688–689.
- WHO, 2003. Global Burden of Diseases (GBD) 2000 Version 3 Estimates, Mortality by Sex, Age, Cause, and WHO Region. <http://www.who.int/healthinfo/bodgbd2000v3/en/index.html> (web site accessed 11/2006).
- Zargar, M., Khaji, A., Karbakhsh, M., Zarei, M.R., 2004. Epidemiology study of facial injuries during a 13 month of trauma registry in Tehran. *Indian J. Med. Sci.* 58 (3), 109–114.