

Trauma

Characteristics of bicycle-related head injuries among school-aged children in Taipei area

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Abstract

Background: Bicycle-related head injury is an important public health issue. A paucity of statistical data on bicycle accidents exists in Taiwan. The purpose of this study was to report the characteristics of bicycle-related head injuries among school-aged children in Taipei, Taiwan.

Methods: Between 2001 and 2002, basic patient information of those with bicycle-related head injuries was collected from the Trauma Data Registry in 5 hospitals of the Taipei area. Telephone interviews were conducted to collect specific information surrounding bicycle accidents.

Results: Of 324 patients with bicycle-related head injuries, 90 (27.8%) had severe head injuries. Boys compared with girls had a higher proportion of severe head injuries (34.1% vs 23.4%; $P = .048$). Children aged 5 to 9 years had a higher proportion of severe head injuries compared with ages 10 to 14 years (65.2% vs 6.4%; $P = .043$). Bicycles without reflectors had a higher proportion of severe head injuries compared to bicycles with reflectors (69.0% vs 5.7%; $P = .004$). Bicyclists carrying goods (such as backpacks or weighted toward the road) and speeding were associated with severe head injury ($P < .05$). Collisions with vehicles of a larger size resulted in a higher rate of severe head injury compared with collisions with pedestrians (76.9% vs 3.6%; $P = .043$).

Conclusions: For children whose main mode of transport is bicycles, the enforcement of helmet legislation, educational programs in bicycling safety and equipment, and improving the infrastructure for bicycling in urban areas are needed in Taiwan to reduce potentially debilitating or life-threatening injuries.

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Keywords:

Bicycle; Head injury; Children

Abbreviation: GCS, Glasgow Coma Scale.

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1. Introduction

Bicycling has become a popular type of transportation in Taiwan and worldwide as a result of growing traffic congestion in urban areas, increased public awareness of environmental protection, economic considerations, and health promotion. However, bicycle-related injuries are an

important health concern because of the increasing use of bicycles [12,22,23,27–29].

According to United States Department of Transportation statistics, the number of bicycle-related injuries was around 534 883 in 2004 to 2005, with 782 bicyclists killed in crashes with motor vehicles [30]. Many studies have been conducted worldwide regarding bicycle-related injuries. Investigations range from describing the characteristics of bicycle accidents, collisions with motor vehicles or pedestrians, the influence of alcohol on head injuries, demographic characteristics, economic characteristics, and roadway and environmental factors [2,11,15,20].

Bicycle-related injury statistics in Taiwan may well be underestimated. To the best of our knowledge, Taiwan has only one study regarding the prevalence and characteristics of bicycle-related injuries in adolescents [23]. Several studies in Taiwan have focused on motorcycle-related traffic injuries [1,14,29], whereas few studies have investigated the characteristics of bicycle-related injuries. A paucity of government and nongovernment statistics are available in Taiwan such as: the number of bicyclists actively riding on the road, accident analysis of bicycle accidents, and incidences of bicycle-related injuries. The lack of comprehensive data on bicycle accidents in Taiwan prevents in-depth analysis of circumstances surrounding bicycle injuries and may fail to reveal to the relevant governmental agencies and to the public the potential dangers associated with bicycle accidents. Without proactive collection of bicycle accident statistics, many bicycle accidents go unreported unless a fatality occurs or when injured bicyclists perceive injuries being not severe enough to seek hospital assistance.

Many school-aged children in Taiwan rely on bicycles to travel to and from school because of the lack of a school bus program similar to that found in the United States. Dangers are increased because of shared congestion on urban roads with other drivers. Compounding this fact is Taiwan's lack of a bicycle infrastructure, such as separate bicycle lanes, programs that promote and educate drivers and bicyclists on traffic safety, and enforcement of traffic laws such as right-of-way. During the present study period, no mandatory bicycle helmet law existed in Taiwan. The purpose of this study was to report the characteristics of bicycle-related head injuries in school-aged children.

2. Methods

Between January 2001 and December 2002, 5 hospitals (including 4 medical centers and 1 regional hospital) in the Taipei area joined the Trauma Data Registry to collect information of patients with trauma. Initially, about 22 123 patients with trauma were included in the Trauma Data Registry, 1832 (8.3%) of which were registered as bicycle-related injuries. Among 1832 patients with bicycle-related injuries, we identified 1412 patients with eligible telephone numbers and addresses. With telephone interviews,

physicians and nurses used questionnaires to interview patients or their families. A supervisor reviewed the completed work for errors and missing data. With informed consent, we successfully interviewed 1132 patients (response rate, 80.2%), 324 (28.6%) of whom had bicycle-related head injuries.

Head injury was defined as injuries to the head, face, or brain. Patients with bicycle-related head injuries were included in this study. Patients who had Glasgow Coma Scale (GCS) scores of 8 or lower were considered to have severe head injuries (case group). Patients with scores of 9 or higher were considered to have mild to moderate head injuries (control group) [26].

We used χ^2 tests to compare demographic factors, bicycle characteristics, and accident information between cases and controls. We considered values of $P < .05$ statistically significant. All analyses were conducted using SAS v.8.1 software (SAS Institute, Cary, NC).

3. Results

We interviewed 1132 patients (response rate, 80.2%), 324 (28.6%) of whom had bicycle-related head injuries. Of the 324 patients with bicycle-related head injuries, 90 (27.8%)

Table 1
Characteristics of cyclists and bicycles

	Head injuries						<i>P</i>
	Severe (n = 90)		Mild (n = 234)		Total (n = 324)		
	n	%	n	%	n	%	
Sex							.048
Girls	45	(23.4)	147	(76.6)	192	(100)	
Boys	45	(34.1)	87	(65.9)	132	(100)	
Age (years)							.043
0-4	32	(24.8)	97	(75.2)	129	(100)	
5-9	43	(65.2)	23	(34.8)	66	(100)	
10-14	7	(6.4)	103	(93.6)	110	(100)	
15-18	8	(42.1)	11	(57.9)	19	(100)	
Use of helmet							.042
No	80	(26.3)	224	(73.7)	304	(100)	
Yes	10	(50.0)	10	(50.0)	20	(100)	
Use of other safety device							.86
Yes	2	(25.0)	6	(75.0)	8	(100)	
No	88	(27.8)	228	(72.2)	316	(100)	
Bicycle with reflectors							.004
Yes	12	(5.7)	199	94.3	211	(100)	
No	78	(69.0)	35	31.0	113	(100)	
Bicycle with bells							.75
Yes	16	(29.1)	39	70.9	55	(100)	
No	74	(27.5)	195	72.5	269	(100)	
Bikers carrying goods							<.001
Yes	65	(90.3)	7	9.7	72	(100)	
No	25	(9.9)	227	90.1	252	(100)	
Biking center of gravity while carrying objects ^a							.035
Inner	17	(7.6)	206	92.4	223	(100)	
Outer	73	(73.0)	27	27.0	100	(100)	

^a Inner, toward the sidewalk; outer, toward the road.

Table 2
Characteristics of bicycle-related accidents in school-aged children

	Head injuries						<i>P</i>
	Severe (n = 90)		Mild (n = 234)		Total (n = 324)		
	n	%	n	%	n	%	
Collisions with others							.043
Large car	40	(76.9)	12	(23.1)	52	(100)	
Small car or taxi	14	(32.6)	29	(67.4)	43	(100)	
Motorcycle	23	(37.7)	38	(62.3)	61	(100)	
Pedestrian	4	(3.6)	107	(96.4)	111	(100)	
Other	9	(15.8)	48	(84.2)	57	(100)	
Bicycle machinery							.024
Loss of control	29	(69.0)	13	(31.0)	42	(100)	
Brake wire out of order	58	(48.3)	62	(51.7)	120	(100)	
Tripped by a roller chain	3	(1.9)	159	(98.1)	162	(100)	
Cause of accident							.031
Greater vehicle speed	62	(44.3)	78	(55.7)	140	(100)	
Inattention/distraction	5	(6.4)	73	(93.6)	78	(100)	
Cycling against traffic flow	23	(21.7)	83	(78.3)	106	(100)	

had severe head injuries (Table 1). Compared with girls, boys had a higher proportion of severe head injury (34.1% vs 23.4%; $P = .048$). Children aged 5 to 9 years had a higher proportion of severe head injury compared with children aged 10 to 14 years (65.2% vs 6.4%; $P = .043$).

The proportion of severe head injuries was higher in children who wore a helmet than in children who did not wear a helmet (50.0% vs 26.3%; $P = .042$) (Table 2). Although patients who wore safety devices, such as elbow or knee protectors, had a lower rate of severe head injury, the difference was not significant ($P = .86$). Bicyclists' bicycles not equipped with reflectors had a higher proportion of severe head injury compared with bicycles with reflectors (69.0% vs 5.7%; $P = .004$). No significant difference in severe head injury was observed for bicycles equipped with bells. Bicyclists carrying goods was a significant factor related to severe head injury ($P < .001$). A further significant difference in the rate of severe head injury was found in bicyclists' center of gravity while carrying objects ($P = .035$).

Collisions with other vehicles of larger size, such as buses or heavy trucks, resulted in a higher rate of severe head injury compared with collisions with pedestrians (76.9% vs 3.6%; $P = .043$). Bicyclists who loss control of their bicycles had a higher proportion of severe head injuries compared with bicyclists who were tripped by the roller chain ($P = .024$). Speeding was also a factor related to severe head injury ($P = .031$).

4. Discussion

Studies have shown that trauma is the leading cause of death among children 5 to 15 years of age in developed and developing countries with traffic fatalities being the predominate mechanism of fatal injury in children [6,10]. In Taiwan, traffic accidents ranked as the third leading cause

of death since 1966, claiming 20 of every 100 000 people in 2006, with bicyclists contributing to 5.8% of the total numbers of fatalities [19]. Compared with Japan data (2004) of 6.7 of every 100 000 people [19], much effort is still required to reduce the number of traffic fatalities due to riding of bicycles in Taiwan. Others researches in Taiwan reported that road collisions involving bicycles were among the top second or third cause of traffic injury [8,9] and the incidences of bicycle-related head injuries ranked second behind motorcycles in the number of traumatic brain injuries caused by traffic accidents [29].

Despite the alarming numbers of fatalities and debilitating injuries cause by bicycles, few statistics and researches are being kept or done with regard to bicycle injuries in Taiwan. To the best of our knowledge, no published study has investigated specifically the characteristics of bicycle-related head injuries in Taiwan. One study surveyed bicycle-related injuries in Taiwan. However, the study was limited to junior high school students; though the study found the severity of bicycling injury was related to the presence of head injury [23], factors contributing to and characteristics of head injury in bicycling accidents were not measured.

The objective of this study is to determine the circumstances related to the head injuries in bicycling accident cases as Taiwan experiences escalating road traffic congestions and the increased environmental awareness of air pollutions caused by automobiles.

Whether age is a contributing factor in bicycle-related injuries has conflicting results. Studies of vehicle accident fatalities in Taiwan and the United States showed that the younger age groups tend to have higher rates of injuries and fatalities [1,22,30]. Our present data showed that the 5- to 9-year and 10- to 15-year age groups comprise most severe head injury cases (44.3% and 44.7%, respectively), with the 5- to 9-year age group having a significant increase in severe head injury ($P = .043$). Our results are consistent with other studies that have found younger age (those <18 years) had a higher risk of bicycle-related injuries in Taiwan and abroad [12,22,23,27,28]. Rodgers [22] posited that younger age groups have less risk perception and are more likely to engage in risky behaviors. In contrast, other studies have reported that the elderly had greater rates of bicycle-related injuries compared with younger adults, and one study showed that age itself was not a causal factor [11,22,25,27]. However, age was strongly associated with relevant variables, such as perceptual motor speed and cognitive development [1,22,30]. We think the explanations offered by various studies to account for differences in bicycle-related injuries among different age groups are valid. The varying objective of different studies, the populations studied, and end points or outcome measured by various studies may contribute to the conflicting data. We suggest further study to clarify the contribution of age to bicycle-related injury.

Our study found boys had a higher proportion of severe head injury than girls. Similar findings have been found in other studies in which males were overrepresented across the

age groups in most transportation injuries as well as bicycling-related injuries [3,5,11,23]. Kim et al [11] considered that male cyclists were more likely to take riskier actions than females while cycling.

Carrying goods on bicyclists' backs and carrying objects that weigh the rider and bicycle toward the road significantly increased the risk of severe head injuries. We suspect the resulting higher center of gravity due to heavy objects on the backs of teenagers, often in the form of backpacks, may increase the risk of losing balance during a collision. Carrying objects toward the road may also be more likely to be caught by passing vehicles. The unanticipated loss of balance causing sudden loss of control and combining with falling toward flow of traffic may subject the cyclist to more significant risk of head impact against vehicles or the road. We recommend continued education of bicyclist in risks associated with carrying heavy objects, correct attachment, and securing of objects to bicycle via bicycle racks or new bicycle design to avoid a higher center of gravity and sudden loss of control of bicycles.

Our study, as well as others, reported that speed and collisions with larger vehicles are risk factors for severe head injury [11,18]. A previous study reported that speed and collisions with larger vehicles increased the probability of fatal injury by 300% [11]. Although we were unable to analyze the significance of collisions with motorcycles, the number of collisions of bicycles with motorcycles coincides with accidents involving larger vehicles with regard to increased severe head injury. Taiwan has a higher density of motorcycles than other countries [1,29] and, thus, a greater chance of collisions with motorcycles. Bicycle and traffic safety courses should be implemented to increase awareness of motor vehicle operators that bicycles and motor vehicles share the same roads and mutual respect of traffic laws are warranted.

Helmet wearers in our study had a higher percentage of severe head injury compared with those who did not wear helmets. Several factors may explain these unexpected data. The percentage of helmet use in our study was rather low (6%), which may not have correctly identified the true effect of wearing a helmet. Many reasons may contribute to a lack of incentives for bicyclists to wear a helmet. Because of the absence of bicycle helmet-related legislation during our study period combined with a lack of public awareness of the risks of cycling-related head injury, riders may not be aware of the need to wear a helmet. With the high population density in Taiwan's urban areas and the short distances needed to travel between locations, riders may further be dissuade from wearing a helmet.

Other reasons for not wearing helmets have been cited by other studies. Howland et al [7] discussed the impact of peer pressure or helmet appearance on the low use of helmets among school-aged teenagers. Hot weather, as reported in Taiwan and other countries, may further dissuade helmet use [1,7,11]. Future research should seek to design effective bicycle helmets that do not sacrifice

protection for cooling. Programs are needed to address the lack of public awareness regarding the possible risks of severe head injuries associated with bicycling.

The subject of bicycle helmet in protecting the bicyclist from significant head injury is not a simple matter compared with motorcycle helmets. Studies have conflicted with regard to the efficacy of wearing bicycle helmets, discrepancies attributed to different helmet designs, or rider behavior [2,24]. Spaite et al [24] reported that bicyclists wearing a helmet tend to ride more carefully, thus, reducing the occurrence of bicycle-related head injuries rather than the helmet itself protecting the rider. Similarly, Curnow [2] argued that studies on the efficacy of bicycle helmets are vulnerable to bias because of various unmeasured factors such as different types of brain injuries caused by forces besides angular momentum (measured most frequently by helmet designers and crash analysis), differing helmet specification requirements, and rider behavior. Nevertheless, legislation for mandatory bicycle helmet use has been introduced in countries such as Spain [13], Canada [21], Australia, and New Zealand [16], and numerous reports have indicated that helmet use was effective in protecting cyclists from bicycle-related trauma and brain injury with reduction in incidences of injury after introduction of mandatory bicycle helmet legislation [7,13,16–18,21,27].

Bicycling has for past few years become more than just a mean of transportation to and from work. For all group ages, bicycling is rapidly becoming a recreational pastime: for fitness and for sports. Economic incentives due to volatile gasoline prices, environmental awareness of Earth's finite natural resources, and of global warming caused by automobile pollution further foster increasing numbers of the public taking up bicycling. This recent trend in Taiwan is further exemplified by political figures being featured in news media cycling throughout the country for political and fitness reasons.

Unfortunately, Taiwan's bicycle-related activities, competition training, bicycle legislation, enforcement of traffic laws, and infrastructure (eg, mandatory bicycle helmet legislation, right-of-way, and separate bicycle lanes), programs that promote and educate motor vehicle operators and bicyclists on traffic safety has not kept pace with the growing number of the bicycle public. Lastly, with estimates showing that 60% to 90% of cycling accidents are not reported [4], the real rate and severity of bicycling-related injury in teenagers may be more serious than the current data suggest. Future research to include greater number of bicycle-related injury cases will be needed to reflect increasing trend of bicycle use and to further clarify characteristics of bicycle-related head injuries.

5. Conclusions

Many school-aged children in Taiwan rely on bicycles as main mode of transportation with dangers increased because

of traffic congestion on urban roads. Measures to reduce motorcycle-related head injuries in Taiwan have been successful in reducing mortality and morbidity associated with motorcycle injury. Similar programs applied to bicyclists may reduce debilitating or life-threatening injuries associated with bicycling.

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Commentary

Because global warming is getting more and more serious, issues of energy conservation and carbon reduction have become very important. Transports with both motorcar and motorcycle are responsible for carbon emission and energy consumption, whereas the bicycle is the only transport vehicle that saves energy and does not emit carbon. In addition, cycling is good exercise for better health. Consequently, bicycling has been actively promoted and has gained popularity in recent years. Furthermore, Taiwan is located in a subtropical area where bicycling is suitable throughout the year. Bicycling has even become a leisure sport among youth groups. Unfortunately, bicycling infrastructure is notoriously inadequate in Taiwan because most roads were originally made or designated for motor vehicles instead of bicycles. There are not enough adequately equipped bikeways or facilities specially designed for bicycle travel. As such, bicycle-related accidents have increased drastically, and bicycle-related injuries involving soft tissues, skeletal organs, and even central nervous systems have increased markedly as well.

The enforcement of bicycling infrastructure and bicycling safety educational programs to reduce the related injuries cannot be overemphasized.

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