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EPIDEMIOLOGY | RESEARCH ARTICLE

Helmets and traffic injury outcomes: Findings from a setting lacking legislation on proper wearing and quality assessment

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Abstract: *Objective:* We assessed the effectiveness of helmet wearing for improving traffic injury outcomes in a setting lacking legislations on proper wearing and quality assessment of helmets. *Methods:* The study included motorcycle riders from Karachi, Pakistan, who were involved in a road traffic crash between 1 January 2007 and 30 September 2013. We estimated likelihoods of death and severe injury in riders wearing helmets compared to those not wearing them. *Results:* Only 6% ($n = 6,092$) of the 109 210 riders wore helmets. Helmet wearing was about 1% in pillion riders, women, and children. About 2% of riders died ($n = 1,949$) and 15% ($n = 16,051$) were hospitalized. About a third of riders ($n = 37,439$, 34%) suffered from head injuries, 30% ($n = 33,130$) had facial injuries, 46% ($n = 50,264$) had extremity injuries, and 61% ($n = 67,094$) had external body injuries. Those wearing helmets were less likely to die (adjusted odds ratio [aOR] = 0.37, 95% confidence interval [CI] = 0.28–0.50) or sustain a severe head injury (aOR = 0.70, 95% CI = 0.55–0.89) than others. The preventive effects however disappeared in high-impact collisions, e.g. heavy vehicles, head-on. *Conclusion:* Helmets effectively reduced the likelihood of deaths and serious head injuries in the injured motorcyclists in Pakistan. Improving legislation and enforcement could help further prevent deaths and serious head injuries in Pakistan and similar settings.

ABOUT THE AUTHORS

The authors have collaborated previously on highlighting the road traffic injury burden in the developing countries, in particularly in Pakistan. This paper presents their work on a road traffic injury surveillance system established in Karachi, Pakistan in 2007. Authors have previously reported that motorcycle injuries are common in these settings and needs actions for prevention.

PUBLIC INTEREST STATEMENT

Motorcycles are a commonly used transport in many developing countries. Those riding the motorcycles are vulnerable to serious injuries and deaths. Helmets can effectively reduce the deaths, yet many countries consistently report low helmet wearing rate. Furthermore, in many developing countries, most of the helmets being worn have not been manufactured as per safety standards. Our study assessed the helmet wearing in seriously injured patients in Pakistan, a low-income country. We also assessed if helmet protected riders from dying or sustaining a serious head injury. We showed that over a six year period from 2007 to 2013 over hundred thousand motorcyclists were treated for road injuries. Of them, only six percent wore helmets, and only one percent of pillion riders were wearing helmets at the time of crash. Wearing a helmet reduced the likelihood of death by almost two-thirds and sustaining a serious head injury by one-third. Our findings indicate a need to strengthen helmet legislation in developing countries.

Subjects: Public Health Policy and Practice; Surgery; Trauma

Keywords: developing country; motorcycle; traffic accident

1. Introduction

Motorcycle riders are one of the most vulnerable road user groups globally (Peden et al., 2004). 'Motorcyclists are over-represented among fatalities and serious injuries (World Health Organization [WHO], 2013). For instance, in some low- and middle-income countries (LMICs), motorcycles account for less than half of registered vehicles yet their riders account for more than half of the road fatalities (Naci, Chisholm, & Baker, 2009). One major determinant of such fatalities is not wearing helmets (Abbas, Hefny, & Abu-Zidan, 2012). Available literature is overall consistent that wearing a helmet during a collision reduces the risk of death by about 32–50% and the risk of severe brain injury by about 62–75% (Liu, Ivers, Norton, Blows, & Lo, 2004; Liu et al., 2008).

The first international directives on how a national helmet legislation needs to be drafted were introduced in 1968 during an international treaty known as the Vienna Convention (Peden et al., 2004). These directives had many limitations, and among others lacked the criteria to assess the quality of a helmet (Jones & Bayer, 2007; Maartens, Wills, & Adams, 2002). The United States government addressed this lacuna in 1974 when it published the first version of quality helmet standards (U.S. Department of Transportation, 2011). Further advances were made in 2002 when the European countries had a consensus on the comprehensive helmet standards known as UNECE 22 (United Nations Economic Commission for Europe, 2002). These regulations included a description of the proper way to wear a helmet as well as the quality standards that a helmet should meet before use. The WHO, therefore, recommends the member nations to consider UNECE 22 for developing their national helmet legislation (WHO, 2006, 2013).

There are still many knowledge gaps about the effectiveness of helmets in the real-world scenarios (Tsai, Wang, & Huang, 1995; Yu, Chen, Chiu, & Lin, 2011). For instance, the two meta-analyses assessing the impact of helmets on traumatic brain injuries only included studies from high-income, resourceful countries, most of which had helmet legislation about proper wearing and quality assessments (Liu et al., 2004, 2008). The LMIC, on the other hand, have a very different situation, i.e. laws often do not cover all riders and lack directives on proper wearing and quality assessment (WHO, 2009, 2013). Other confounders affecting the interpretations of literature include the greater share of motorcycles in traffic, speeds on roadways, road quality, and driving practices (Peden et al., 2004; Road Traffic Injuries Research Network Multicenter Study Collaborators et al., 2013). These differences could be a significant significant impediment to applying the available work on helmet effectiveness to LMICs (Liu et al., 2004, 2008; WHO, 2006, 2013).

In the above situation, an ambiguity arises that whether helmets are effective in preventing serious traumatic brain injuries in a setting lacking standard helmet legislation and enforcement (Kraus, Rice, Peek-Asa, & McArthur, 2003; Liu et al., 2004, 2008). We assessed the effectiveness of helmets on injury outcomes in one such setting that had no directives about proper wearing and quality assessment of helmets.

2. Methods

2.1. Study setting and design

The study setting was Karachi, Pakistan. It is the most populous metropolis of Pakistan with over 17 million inhabitants (Government of Pakistan, 2001, 2009). Motorcycles, with engine power ranging from 70 to 125 cc, account for about two-thirds of the registered motor vehicles in Karachi (Shamim, Razzak, Jooma, & Khan, 2011). The study data were extracted from a surveillance system of road traffic injury patients established in five high-volume emergency departments in Karachi, namely, the Jinnah Post-Graduate Medical Centre, Abbasi Shaheed Hospital, Liaquat National Hospital, Aga

Khan University Hospital, and Civil Hospital Karachi. A description of this surveillance system is available elsewhere (Razzak et al., 2012). All road trauma patients presenting to these centers were eligible for inclusion in this study. Previous work indicated that these centers received almost half of the road fatalities in the city (Lateef, 2010). The study was approved by the Institutional stakeholders including the Heads of Departments of the Accident and Emergency in all five hospitals. Additionally, the study was approved by the Ethics Review Committee (ERC) of the Aga Khan University (Ref. 806-Med/ERC-07).

2.2. Study population

For this study, we included only those patients who were riding a motorized two-wheeler (or a motorcycle hereafter) including pillion riders and who were treated for injuries at the selected emergency departments between 1 January 2007, and 31 December 2013 (Ahmed, 2007). While the legal age for driving in Pakistan is 18 years, this study included patients younger than 18 years because of anecdotal reports suggesting that also rode motorcycles as drivers without a license. This study excluded patients of whom we had no information regarding helmet wearing at the time of the crash.

2.3. Measures

We used information about riders including gender, age, rider type (driver or pillion), whether helmet was worn, collision type (e.g. between motorcycle and car) and by impact (head-on, rear-end, hit object or from side), and injury severity based on the Abbreviated Injury Scale-1998 (AIS) (Stevenson, Segui-Gomez, Lescohier, Di Scala, & McDonald-Smith, 2001). AIS is available for anatomical body regions including head, face, chest, abdomen, extremity, and external body, and is recorded as mild “1” to maximum “6” (Stevenson et al., 2001). The assistants who collected data in the emergency departments received specific training before they started coding and reporting the injury severity. The riders were followed only during their emergency department admission. Three outcomes were noted: discharge, hospitalization, or death (Shamim et al., 2011).

2.4. Analyses

For the analyses, age was categorized into four groups: <18 years, 18–25 years, 26–45 years, and 46 years or older. We did not further sub-categorize the age groups for the statistical comparisons with the largest age group 18–25 years accounting for about two out of five motorcyclists. The injury severity for body regions was categorized as mild (AIS = 1), moderate (AIS = 2), and severe ($3 \leq \text{AIS} \leq 6$) (Stevenson et al., 2001). The New Injury Severity Score (NISS) that represented overall injury severity was computed from the square of the three highest AIS scores (AIS = 6 was recoded as AIS = 5 for NISS computations). The NISS ranged from 1 to 75 and based on the literature (Stevenson et al., 2001), it was categorized as mild (1–3), moderate (4–8), and severe (9–75) injury. Helmet use was compared by patient characteristics including age, gender, rider status (e.g. pillion rider), involved vehicles, injury severity by body region and overall, and for outcomes at an emergency department.

To assess whether helmets reduced the likelihoods of specific injury outcomes, nine logistic regression models were computed for specific outcomes as a dependent variable. In the first two models, we compared the likelihood of deaths and hospital admissions in patient wearing helmets vs. those not wearing helmets with emergency department discharge as a reference category in each model. In the third model, the likelihoods of severe body injury, i.e. $\text{NISS} \geq 9$ (reference: $\text{NISS} < 9$) were compared in patients wearing helmets vs. patients not wearing helmets. Lastly, we computed six separate logistic regression models to assess whether helmeted patients were less likely to suffer severe injury ($\text{AIS} \geq 3$) to a specific body region including head, face, chest, abdomen, extremity, and external skin. Separately, we also performed sub-group analyses to assess whether helmet-associated effects on head injuries persisted under different crash conditions. Hence, we computed logistic regression models with severe head injury ($\text{AIS} \geq 3$) as the main dependent variable and helmet

wearing as the main independent variable in different patient sub-groups defined by the type of crash and crash impact. The estimated odds ratio, 95% confidence intervals and *n* were presented for each model. All models were adjusted for age, gender and rider type.

3. Results

3.1. Sample

A total of 140,107 motorcyclists were injured during the study period. After excluding patients without helmet data, about 77.9% (*n* = 109,210) were included in the analysis (Table 1). Most patients were males (93.3%), aged 18–25 years (41.2%), and drivers (81.0%). In about 39.7% (*n* = 43,363) of riders, collisions involved other vehicles, e.g. cars (36.0%), motorcycles (23.4%), trucks (14.8%), buses (13.0%), and three-wheelers (12.7%). The crash impacts were available in 43.7% (*n* = 46,676) of riders: most of them were side/merging (39.6%) or rear impact crashes (36.1%). Head-on collisions accounted for 19.5% of these crashes. About 34.3% (*n* = 37 439) patients had a head injury, 30.3% (*n* = 33,130) had a facial injury, 1.5% (*n* = 1,624) had a chest injury, 4.7% (*n* = 5,171) had an abdominal injury, 46.0% (*n* = 50,264) had an injury to extremities, and 61.4% (*n* = 67,094) had an injury to external body regions. About one in four patients (26.4%, *n* = 28,723) suffered from moderate bodily injury whereas 13.1% suffered from a severe bodily injury as per NISS. While most patients were discharged (83.4%), about 14.7% were hospitalized, and 2.4% died in the emergency department.

3.2. Helmet wearing

Of the 109,210 patients, only 5.6% wore helmets. Helmet use was higher in men compared to women (6.8 vs. 0.4%). Helmet wearing was below average in riders aged < 18 years (1.4%) and those aged 18–25 years (4.5%). Helmet wearing was lower in pillion riders compared to riders (0.3 vs. 6.8%). Helmet wearing was also lower in collisions involving single-vehicle or when no other vehicle was reported (4.3%, *n* = 2,540) or when the vehicle hit an object (4.6%, *n* = 105). Helmet wearing was comparatively lower in those who died (2.4%, *n* = 46).

Helmet wearing had a protective effect on moderate and severe head injury (Table 2). For example, the proportion of severe head injury was 13.9% in those wearing helmets compared to 17.6% in those not wearing helmets. Except for chest injuries, similar effects were not observed for other body regions.

The multivariate logistic regression analysis showed that helmet wearing was associated with decreased likelihood of death (adjusted odds ratio [aOR] = 0.37, 95% confidence interval [95% CI] = 0.28–0.50) (Table 3). The findings were unchanged when severe injuries to anatomical regions other than the head region were excluded (not shown). On the other hand, helmet use increased the likelihood of hospitalization (aOR = 1.24, 95% CI = 1.16–1.32). However, these findings were reversed after excluding patients with severe injuries to anatomical regions other than head showing that helmet use reduced the likelihood of hospitalization related to head injuries (aOR = 0.85, 95% CI = 0.78–0.93). Helmet wearing had no significant effects on overall injury severity. The analysis of injury severity confirmed above indicating that helmets decreased the likelihood of sustaining a severe head injury (aOR = 0.70, 95% CI = 0.55–0.89). Helmet use was also associated with decreased likelihood of severe chest injuries, though overall prevalence of these injuries was low. Helmet wearing was associated with increased odds of extremity injuries (aOR = 2.34; 95% CI = 2.10–2.60) and external skin injuries (aOR = 20.07; 95% CI = 14.86–27.11).

In the sub-group analyses, the likelihood of severe head injury was lower than above point estimate when collisions involved motorcycle with another motorcycle (aOR = 0.30; 95% CI = 0.09–0.95) or motorcycle with a car (aOR = 0.42; 95% CI = 0.22–0.78). Other analyses indicated that the effects of helmets on reducing severe head injuries were not significant in subgroups of patients involved in collisions with buses and trucks, head-on impact, hitting objects, and side-impact (Table 4).

Table 1. Helmet wearing in motorized two-wheeler riders in Karachi, Pakistan (2007–2013)

	Total		Helmets		Without helmets	
	N	%	N	%*	N	%*
Total	109,210	100.0	6,092	5.6	103,118	94.4
Rider status						
Rider (Driver)	88,498	81.0	6,025	6.8	82,473	93.2
Pillion rider (Occupant)	20,715	19.0	67	0.3	20,645	99.7
Gender						
Male	101,889	93.3	6,065	7.0	95,824	93.0
Female	7,280	6.7	24	0.4	7,256	99.6
Age						
<18	14,969	13.8	215	1.4	14,754	98.6
18–25	44,741	41.2	2,015	4.5	42,726	95.5
26–45	41,117	37.8	3,307	8.0	37,810	92.0
≥46	7,853	7.2	505	6.4	7,348	93.6
Multiple vehicle crashes*						
Motorcycle × Motorcycle	10,143	23.4	653	6.4	9,490	93.6
Motorcycle × 3 wheelers	5,522	12.7	393	7.1	5,129	92.9
Motorcycle × Cars	15,608	36.0	1,252	8.0	14,356	92.0
Motorcycle × Bus	5,657	13.0	427	7.6	5,230	92.4
Motorcycle × Trucks	6,433	14.8	521	8.1	5,912	91.9
Crash impact						
Head-on	9,086	19.5	587	6.5	8,499	93.5
Rear-end	16,851	36.1	1,245	7.4	15,606	92.6
Hit object	2,263	4.8	105	4.6	2,158	95.4
Side/merging	18,476	39.6	1,412	7.6	17,064	92.4
Body region injured						
Head	37,439	34.3	639	1.7	36,797	98.3
Face	33,130	30.3	732	2.2	32,398	97.8
Chest	1,624	1.5	262	16.1	1,362	83.9
Abdomen	5,171	4.7	202	3.9	4,969	96.1
Extremities	50,264	46.0	3,311	6.6	46,953	93.4
External body parts	67,094	61.4	3,079	4.6	64,015	95.4
New Injury Severity Score (NISS)						
Mild (NISS 1–3)	65,728	60.5	2,964	4.5	62,764	95.6
Moderate (NISS 4–8)	28,723	26.4	1,792	6.2	26,931	93.8
Severe (NISS 9–75)	14,195	13.1	772	5.4	13,426	94.6
Outcome						
Emergency discharge	90,925	83.4	4,839	5.3	86,086	94.7
Admission/referred	16,051	14.7	1,152	7.2	14,899	92.8
Deaths	1,949	1.8	46	2.4	1,903	97.6

*Excludes single vehicle crashes or those where another vehicle was not determined ($n = 59,482$). Helmet use in these patients was 4.3% ($n = 2,540$).

Table 2. Injury severity according to the body region involved in motorized two-wheeler riders in Karachi, Pakistan (2007–2013)

	Injury severity		
	Minor (AIS = 1)	Moderate (AIS = 2)	Severe (3 ≤ AIS ≤ 6)
	%	%	%
Head			
With helmets	53.2	32.9	13.9
Without helmets	45.9	36.6	17.6
Face			
With helmets	70.9	27.1	2.0
Without helmets	78.4	19.6	2.0
Chest			
With helmets	60.3	33.2	6.5
Without helmets	56.0	32.2	11.8
Abdomen			
With helmets	40.1	49.5	10.4
Without helmets	56.0	36.4	7.6
Extremities			
With helmets	40.2	45.0	14.8
Without helmets	60.0	32.9	7.1
External body parts			
With helmets	91.2	5.5	3.3
Without helmets	97.7	2.0	0.3

Note: AIS – Abbreviate Injury Scale.

Table 3. Injury outcomes in helmeted vs. without helmet riders in Karachi, Pakistan (2007–2013)

	n	Helmeted vs. non-helmeted	
		Adjusted* odds ratio	95% confidence intervals
Emergency outcomes (ref: ED discharge)			
Death	108,370	0.37	0.28–0.50
Admission	106,435	1.24	1.16–1.32
Severe injury (ref: mild to moderate injury)			
New Injury Severity Score ≥ 9	108,099	0.97	0.90–1.05
Abbreviated Injury Scale— Head ≥ 3 [†]	35,758	0.70	0.55–0.89
Abbreviated Injury Scale— Face ≥ 3 [‡]	28,716	1.75	0.95–3.23
Abbreviated Injury Scale— Chest ≥ 3 [‡]	1,272	0.52	0.28–0.98
Abbreviated Injury Scale— Abdomen ≥ 3 [‡]	4,767	1.56	0.94–2.59
Abbreviated Injury Scale— Extremity ≥ 3 [‡]	48,023	2.34	2.10–2.60
Abbreviated Injury Scale— External skin ≥ 3 [‡]	62,474	20.07	14.86–27.11

Note: ED = Emergency department.

*Adjusted for age, gender, and rider status.

[†]Without severe injury (AIS ≥ 3) to face, chest, abdomen, extremities, or skin.

[‡]Without severe injuries (AIS ≥ 3) in another body region.

Table 4. Sub-group analyses of the effects of patient and crash factors on severe head injury by helmet use

Sub-groups	n	Helmeted vs. non-helmeted	
		Adjusted odds ratio*	95% confidence intervals
Abbreviated Injury Scale—Head \geq 3 (ref: Abbreviated Injury Scale—Head \geq 3)			
Multiple vehicle crashes			
Motorcycle \times Motorcycle	3,244	0.30	0.09–0.95
Motorcycle \times Cars	5,552	0.42	0.22–0.78
Motorcycle \times Bus	2,189	0.85	0.46–1.57
Motorcycle \times trucks	2,571	0.76	0.45–1.29
Crash impact			
Head-on	3,291	0.65	0.34–1.22
Rear-end	7,101	0.59	0.36–0.97
Hit object	791	0.74	0.15–3.59
Side/merging	4,603	0.60	0.32–1.12

*Adjusted for age, sex, and rider status (e.g. pillion rider).

4. Discussion

This large sample study assessed whether helmets were effective in a setting that had no laws about proper wearing and quality assessment. Consistent with previous studies, we found that helmet wearing was low in riders of Karachi (Bhatti, Ejaz, Razzak, Tunio, & Sodhar, 2011; Khan, Khan, Aziz, Islam, & Shafqat, 2008; Khan et al., 2015; Shamim et al., 2011). We also noted that helmet wearing was comparatively lower in pillion riders, women, and children. Our findings indicated that riders who died were less likely to wear helmets than those who survived. The study showed that helmets might cut the odds of severe head injury by almost one-third. Findings indicated that helmets also reduced the likelihood of severe head injuries and related hospitalizations. The preventative effects of helmets on severe head injuries disappeared in collisions involving heavy vehicles, head-on, hitting objects, and side-impact.

This study confirmed that helmets can be effective in preventing death and severe head injury even when existing laws did not cover proper wearing or quality assessment. This work provides the impetus that achieving a 100% enforcement of helmets in similar settings would decrease the related injury burden. The findings also indicated that enforcement campaigns in a low-helmet use setting should not neglect specific groups such as women, pillion riders, and youth (Khan et al., 2015; Shamim et al., 2011).

While this study showed that helmets decreased the likelihood of sustaining a severe head injury, the observed effect size was much lower than the one supported in previous meta-analyses, e.g. point estimates of summary odds ratio ranged from 0.28 to 0.31 (Liu et al., 2004, 2008). This study also showed that the likelihood of sustaining a moderate injury to face was higher in those wearing helmets than others. One possibility for these findings is that the helmets were improperly worn in some patients. Alternately, it is possible that helmets lacked essential protection capacity, a problem that might have been avoided through systematic quality assessments of new helmets. A previous study from Pakistan did show that about half of riders wore a helmet that did not meet the international manufacturing standards (Road Traffic Injuries Research Network Multicenter Study Collaborators et al., 2013).

The disappearance of the effects of helmets effectiveness in severe crashes could be suggestive of issues in helmets' quality and manufacturing standards. It might also be possible that these types of severe crashes resulted in involvement of severe injuries to other critical body parts. Previous work consistently supports that a helmet that is tested and is properly-worn helmet could reduce the risk of a death and a head injury by almost half (Tsai et al., 1995; Yu et al., 2011). Taken together, the findings support that further clarifications about quality of helmets being worn by severely injured patients would be needed to comprehensively assess rider safety in Pakistan.

This study has several limitations. Firstly, a significant proportion of patients had missing data about helmet use which might have led to underestimation of effect size (I. Khan et al., 2008). Further, many fatalities and severe crashes go unreported in Pakistan (Kayani, Fleiter, & King, 2014), that might also underestimate the effectiveness of helmet use. Similarly, information about other vehicles and impacts during collisions was not available for a significant proportion of riders. Despite above limitations, overall the results supported the need to improve helmet legislation and enforcement in Pakistan.

In conclusion, we recommend that increasing helmet wearing needs to be a priority in Pakistan, and campaigns should also target most vulnerable groups such as women, youth, and pillion riders. More importantly, these findings provide an impetus for settings of a similar socioeconomic situation to consider improving existing laws to international standards regarding directives about helmet wearing and quality assessment.

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Competing interests

The authors declare no competing interest.

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Authors contribution

RJ led the study. JAR and URK provided support in data collection, training, and analyses. JAB led the analysis and report writing. All authors read and approved the final version of the manuscript.

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