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Helmet use among motorcycle riders in Ho Chi Minh City, Vietnam: results of a five-year repeated cross-sectional study

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ABSTRACT

Objective: In Vietnam, motorcycle riders comprise about three-quarters of road traffic fatalities, the most common cause of which is head injuries that can be prevented by wearing a helmet. This study aims to assess helmet-wearing behaviors in Ho Chi Minh City, the largest city in Vietnam.
Methods: Eight rounds of observational studies were conducted in six randomly selected locations between July 2015 and April 2019. Given the multinomial nature of the outcome measure (not wearing a helmet; wearing a substandard helmet; wearing an unstrapped standard helmet; wearing a strapped standard helmet), a multinomial model was developed to estimate the level and trend of helmet use and identify the related individual and environmental factors.
Findings: A total of 479,892 motorcycle riders were observed, over 90 % of whom were wearing helmets (range over the eight rounds: 92.5 %–96.0 %). However, the prevalence of correct helmet use (defined as wearing a strapped standard helmet) gradually declined from 80.8 % in round 1–55.6 % in round 8. Results from a multinomial model showed the probability of wearing a strapped standard helmet had declined by 22.4 percentage points from round 3 to round 8 while holding other factors constant (95 % CI: 21.8–23.0). The prevalence of correct use is 11.3 percentage points higher for adults than for children (95 % CI: 10.5–12.1). During the same period, unstrapped standard helmet use increased by 24.5 percentage points (95 % CI: 24.1–24.9); substandard helmet use declined but remained high.
Conclusion: The upward trend of incorrect helmet wearing behaviors and wearing substandard helmets sends a rallying call for multisectoral interventions.

1. Introduction

Road traffic crashes cause tremendous health and economic burdens in Vietnam, a lower-middle-income country with 96.8 million people and 50.7 million registered vehicles. According to the World Health Organization (WHO), 24,970 people died from road traffic crashes in the country in 2016 (WHO, 2018). The death rate of 26.4 per 100,000 population remained nearly the same as in 1990 (WHO, 2018). From an international perspective, that death rate is 45 % higher than the global average and 28 % higher than the regional average in Southeast Asia (WHO, 2018). Road traffic crashes also cause a large number of non-fatal injuries. WHO estimates 1,253 disability-adjusted life years (DALYs) per 100,000 population due to road traffic crashes. Additionally, road traffic crashes result in an economic loss estimated equivalent to 2.5 % of the nation's GDP (WHO, 2018; Nguyen et al., 2013a).

Motorcycles account for 95 % of vehicles in Vietnam and are the primary mode of transport for most Vietnamese people (Le and Blum, 2013). National data on deaths by user type are not available, but a sample mortality surveillance system comprising 192 communities in 16 provinces found that about three-fifths of road traffic fatalities were motorcycle users (Ngo et al., 2012). Head injuries are the most common cause of motorcyclist deaths (78 %) (Ngo et al., 2012). Hospital-based studies revealed a similar situation at the local level. One study showed that over three-quarters of motorcyclist deaths were attributed to head injuries (Ivers et al., 2014). Another study found that head injuries accounted for 70 % of motorcycle-related hospitalizations and none of the motorcyclist deaths were recorded wearing a helmet (Ha et al., 2018).

Motorcycle riders are more vulnerable in crashes than four-wheeled vehicle passengers because they are not surrounded by the energy-absorbing structures of a four-wheeled vehicle (Bhalla and Mohan, 2015). Since head injuries are the most common cause of death in crashes involving motorcycles, helmet use has been promoted globally for the safety of all riders involved in such crashes. Correctly wearing a helmet can result in a 42 % reduction in risk of death from a crash and almost a 70 % reduction in risk of severe injury (WHO, 2018). The best practice for a helmet law covers all users and all roads and engine types, and requires riders to both wear and properly strap a standard helmet while riding a motorcycle (WHO, 2018). In this report, a standard or certified

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helmet refers to a helmet that conforms to the country's helmet standard TCVN 5756 for adults and TCVN 6979 for children. On the other hand, a substandard or uncertified helmet refers to one that does not conform to the standards.

Vietnam introduced and amended helmet legislation between 2000 – 2003. The legislation covered provincial roads and national highways but excluded motorcycles in urban areas. The penalty for violations was only less than US$2, and enforcement was weak. As a result, the legislation was insufficient to bring about the expected behavior changes. The helmet-wearing rate remained at a low level of 30 % according to studies conducted in 2004 and 2005 (Le and Blum, 2013; Hung et al., 2006). To further promote helmet wearing, Vietnam adopted a comprehensive motorcycle helmet-use legislation that came into effect on 15 December 2007 (Passmore et al., 2010). It made helmet use mandatory for all riders on all roads, increased fines up to six times, and strengthened enforcement. Although no national surveys were conducted before and after the implementation of the legislation, several local surveys found that helmet use rate increased from 30 % to over 90 % within a few months of implementation (Hung et al., 2006; Nguyen et al., 2013b). Consequently, rates of head injuries and deaths among motorcycle riders significantly decreased (Ha et al., 2018). A simulation study found the comprehensive legislation had tremendous health and economic benefits at the population level (Olson et al., 2016).

Despite the immediate success, the 2007 helmet use law had several loopholes. First, it did not include a penalty for unstrapped or loosely strapped helmets (See Appendix A for the illustrations of unstrapped or loosely strapped helmets). Even a minor impact in an accident can dislodge an unstrapped or displace a loosely strapped helmet, leaving the head unprotected as if not wearing a helmet (Richter et al., 2001; Richards, 1984). A study found that loosely strapped helmets nearly doubled the risk of head injury compared to firmly strapped helmets (Yu et al., 2011). A 2008 amendment to the legislation specified that wearing unstrapped helmets would be penalized as if no helmet was worn.

The second loophole is on the type or quality of helmets. Due to the hot weather in Vietnam, a full-face helmet is uncomfortable to wear. To encourage helmet use and facilitate enforcement, the helmet use law allows tropical helmets. This helmet type is much lighter but still provides sufficient impact protection in urban areas where travel speed is usually low due to traffic congestion (Passmore et al., 2010; Yu et al., 2011). See Appendix A.1 for the illustrations of different helmet types. However, the inclusion of tropical helmets might have contributed to the use of substandard helmets that provide minimal protection. Many substandard helmets look like tropical helmets, making enforcement difficult.

The third loophole was on children. The 2007 legislation did not include a penalty for adults for carrying children not wearing helmets. In April 2010, the Prime Minister signed Resolution 32, Decree 34/2010/ND-CP to close the loophole by explicitly specifying that adults carrying children not wearing a strapped helmet will be fined. With rules and laws tightening the use of helmets, many motorcycle riders, particularly young people, wear substandard helmets and do not always strap their helmets. A repeated cross-sectional study conducted in two Vietnamese cities between 2011–2014 found that less than 80 % of the observed motorcycle riders were correctly wearing standard helmets (Bao et al., 2017).

In parallel with the legislative interventions, Vietnam has actively participated in the international network on road safety. In 2007, Vietnam was included in a pilot project funded by Bloomberg Philanthropies, aiming to encourage the adoption of proven traffic regulations (Toroyan, 2007). The collaboration was renewed in 2010 through another five-year Bloomberg Philanthropies funded project in 10 low- and middle-income countries (Bachani et al., 2013). The helmet use rate increased in the project cities in Vietnam during the evaluation period (Bao et al., 2017). The collaboration continues with Ho Chi Minh City (HCMC) joining the Bloomberg Initiative for Global Road Safety (BIGRS) 2015–2019, a consortium of international partners funded by Bloomberg Philanthropies (Larson et al., 2016). The BIGRS project aims to improve road safety in 10 selected cities in low- and middle-income countries. Project activities include social marketing that promotes best practices on road safety, policy development and implementation support, infrastructure renovation, and police capacity in enforcement strengthening.

Despite the extensive studies on this issue, there is still an urgent need for evidence to inform policy revisions and enforcement activities in HCMC and the nation. In particular, few studies presented a temporal trend and distinguished correct and incorrect wearing. Therefore, the objective of this study was to provide an updated assessment of helmet use behaviors in HCMC. The specific goals include: 1) estimate the prevalence of helmet use from a city-level representative sample, with a focus on correct helmet use; 2) assess the temporal trend of helmet use behaviors through multi-round cross-sectional observations; and 3) identify individual and environmental factors affecting helmet use behaviors.

2. Data and methods

As part of the BIGRS measurements and evaluation strategies, roadside observations were conducted on helmet use behaviors. Six observational sites were randomly selected based on a standardized protocol to systematically survey a representative proportion of the local traffic. All eligible sites meet the following criteria: 1) location must be safe for observers; 2) observers may be located at an elevation that is higher or equal height to passing vehicles; and 3) locations where the local population, rather than tourists, are more likely to be observed.

Data collection covered both business days and weekends; it also covered the whole period from 07:00 to 21:00 h, providing a full representation of varying traffic models during both rush and non-rush hours.

At each site, trained field workers observed helmet use for all passing motorcycles. Each observation period and location was staffed by two researchers, with one observing and the other recording the information in a structured form. We developed rigorous protocols for quality control. Specific actions include: 1) comprehensive training on study protocols and observational skills before each round; 2) abundant practice opportunities; 3) close supervision throughout the entire observation process; and 4) thorough quality check before data use.

The observers collected information on the visually estimated age and sex of all drivers and passengers, whether the user was wearing a helmet, type of helmet, and whether the helmet was strapped. Regarding the helmet type, our observers were only able to distinguish cap and non-cap helmets. Although cap helmets constitute a majority of substandard helmets, non-cap-looking helmets may also be substandard. Consequently, our results may underestimate the prevalence of substandard helmet use. Site description including weather, traffic volume, road surface conditions, number of lanes, and whether law enforcement activities were collected before each observation session. All data were recorded on the sites. We initially tested the videotaping approach but found it more difficult to obtain accurate observations. For example, it is harder to tell whether a helmet is firmly strapped in videos than on-site.

The observational method has been extensively used in road safety studies (Akaateba et al., 2014, Wu et al., 2012, Li et al., 2018). This method provides access to road safety behaviors of interest in real-life situations, has stronger validity than interviews that are vulnerable to misreporting, and can reach a wide range of people at a reasonable cost (Boyko, 2013). Comprehensive training was provided to all field workers before the first round of data collection. And refresher training was repeated before each subsequent round.

Both descriptive statistical methods and a multinomial model were used to analyze the data. Every observed motorcycle rider had four possible statuses regarding helmet use: nonuser; substandard helmet user; unstrapped standard helmet user; strapped standard helmet user (Fig. 1). Unless specified otherwise, unstrapped also included loosely strapped. Accordingly, a multinomial model was developed to predict the four possible outcomes simultaneously. The model specification can be expressed as below.

$$\Pr(c_i = kX_i) = \frac{\exp(X_i\beta)}{\sum_i \exp(X_i\beta)}$$

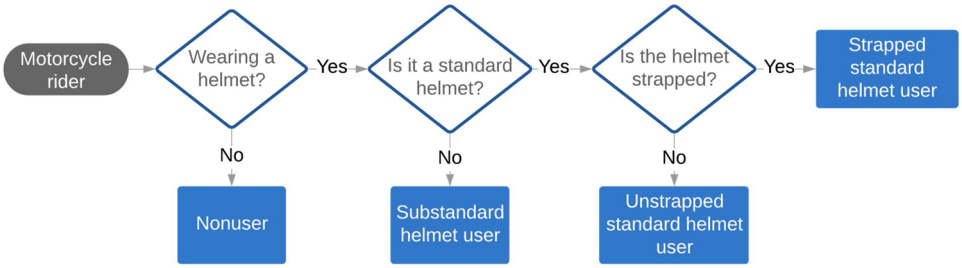

Fig. 1. Types of Helmet-Wearing Behaviors.

Table 1
Description of the samples in eight rounds of observational studies in HCMC.

Characteristics	Round								Total
	1	2	3	4	5	6	7	8	
Total	**94,889**	**88,874**	**32,086**	**30,019**	**39,664**	**60,616**	**68,134**	**65,610**	**479,892**
Sex									
Male	NA	NA	17,785	17,692	23,569	36,591	41,588	41,229	178,454
Female	NA	NA	14,301	12,327	16,095	24,025	26,546	24,381	117,675
User Type									
Driver	68,731	65,907	15,376	21,789	29,727	44,724	52,330	51,029	349,613
Passenger	26,158	22,967	16,710	8,230	9,937	15,892	15,804	14,581	130,279
Age									
< 18 years	NA	NA	4,832	2,663	2,827	4,697	3,947	3,633	22,599
> = 18 years	NA	NA	27,254	27,356	36,837	55,919	64,187	61,977	273,530
Weather									
Clear	NA	NA	31,217	28,110	34,656	52,399	63,849	65,610	275,841
Rainy	NA	NA	869	1,909	5,008	8,217	4,285	NA	20,288
Day of Week									
Weekday	43,478	43,423	13,713	17,381	26,860	39,686	43,738	43,335	271,614
Weekend	51,411	45,451	18,373	12,638	12,804	20,930	24,396	22,275	208,278
Time of Day									
Morning	41,819	40,209	15,755	10,861	16,401	23,107	26,973	25,653	200,778
Afternoon	27,174	26,096	7,995	12,324	14,826	23,592	27,165	26,040	165,212
Early Evening	25,896	22,569	8,336	6,834	8,437	13,917	13,996	13,917	113,902

where β is the associated vector of coefficients; c_i is a multinomial measure for motorcycle rider i denoting his/her helmet-wearing behavior ($k = 0$ for nonuser, the base outcome; $k = 1$ for substandard helmet user; $k = 2$ for unstrapped standard helmet user, $k = 3$ for strapped standard helmet user); X_i is the covariate vector for rider i including an intercept. The covariates included in the model are round of observation, sex of motorcycle rider (male; female), type of rider (driver; passenger), age (< 18 years; > = 18 years), day of week (weekday; weekend), time of day (morning 7:00–12:00, afternoon 12:01–17:00, early evening 17:01–21:00), and weather condition (clear; rainy).

There are two other potential analytical approaches for a multinomial outcome: separate modeling and sequential modeling. In the separate modeling approach, pairs of outcome values are compared in separate models, such as nonuser vs. substandard helmet user, nonuser vs. strapped standard helmet user. The sequential modeling approach includes separate models for each level (level 1: user vs. nonuser; level 2: substandard vs. standard among users; level 3: strapped vs. unstrapped among standard helmet users). The disadvantage of the separate and sequential modeling approaches is that they do not fully utilize all the data points, resulting in a loss of statistical power.

The model coefficients from a multinomial model measure the impact of a one-unit change in a model covariate on the odds of observing a given outcome value compared to the base outcome value. Nonuser is used as the base outcome in the model, and the other three possible outcome values are compared against it. The coefficients from a multinomial model can also be expressed in odds ratios. Due to the nonlinear nature of the model, the covariate impact varies with covariate value.

The BIGRS project aims to reach the non-technical audience, including policymakers, who may not find coefficients or odds ratios from a multinomial model sensible. Therefore, results from the logistic models are converted to average marginal effects (AME) that has a more straightforward interpretation (Williams, 2012).

Individual-level demographic indicators were not recorded in rounds 1 and 2. As a result, the multinomial regression model only used data from rounds 3 – 8. All data analyses were conducted in Stata 15 SE (StataCorp, 2017). Ethical and institutional approval was obtained from Johns Hopkins Bloomberg School of Public Health, USA.

3. Results

Between July 2015 and April 2019, eight rounds of observational studies on helmet use were conducted with a sample size of 479,892 motorcycle riders (Table 1). Rounds 1–2 did not keep individual records and therefore are excluded from some disaggregation and the multinomial regression. 73 % of observed motorcycle riders were drivers, 60 % were males, and 92 % were adults. Most observations were conducted in clear weather (93 %), and more than half were on weekdays (56 %).

We calculated the prevalence of two types of helmet use: 1) any helmet use defined as wearing a helmet regardless of the helmet type or

Table 2
Helmet-wearing rate by characteristics and by round in HCMC.

Characteristics	Round							
	1	2	3	4	5	6	7	8
Total	96.0	95.1	93.4	92.7	94.5	91.1	93.5	92.5
Helmet Type								
Cap helmet	NA	NA	11.8	11.5	13.8	6.4	5.6	5.9
Non-cap Helmet	NA	NA	81.6	81.1	80.7	84.7	87.9	86.5
Sex								
Male	NA	NA	92.3	92.3	94.2	90.9	93.3	92.5
Female	NA	NA	94.8	93.2	94.9	91.5	93.8	92.4
User Type								
Driver	98.5	97.7	98.1	96.3	97.8	95.6	96.4	95.3
Passenger	89.3	87.7	89.0	83.0	84.8	78.4	84.2	82.6
Age								
< 18 years	NA	NA	82.2	57.6	55.4	41.5	49.4	49.3
> = 18 years	NA	NA	95.4	96.1	97.5	95.3	96.2	95.0
Weather								
Clear	NA	NA	93.3	92.7	94.3	91.0	93.4	92.5
Rainy	NA	NA	97.0	92.0	96.3	91.9	96.0	na
Day of Week								
Weekday	95.9	95.5	93.8	94.0	95.5	91.7	94.0	92.7
Weekend	96.0	94.7	93.1	90.8	92.4	90.0	92.7	92.0
Time of Day								
Morning	96.1	95.9	94.8	92.7	94.7	91.3	93.5	93.4
Afternoon	96.1	94.4	92.6	93.5	95.2	92.1	94.2	92.8
Early Evening	95.7	94.6	91.4	91.1	93.0	89.1	92.1	90.1

whether it was strapped; and 2) correct helmet use defined as wearing a standard helmet and it was strapped.

Across the eight rounds, over 90 % of motorcycle riders were observed wearing helmets (Table 2), confirming the results from earlier studies (Hung et al., 2006). Drivers were more likely to wear helmets than passengers, but the difference was small, ranging from 7 % to 13 % over time (Fig. 2). The most considerable difference was observed between adult and child riders. Particularly in recent rounds, nearly all adults wore helmets while only about half of child riders did. In addition, there were minor variations by weather, day of week, and time of day.

The correct helmet use rate was substantially lower than the overall use rate (Table 3). It started with a relatively high level of 81 % in round 1 but gradually declined to slightly over 50 % in recent rounds (Fig. 2). Unlike the overall helmet use rate that does not show a gender difference, the correct helmet use rate was consistently higher among males than females (except round 3). Drivers and adults were more likely to be correctly wearing helmets than passengers and children.

By definition, the change in the correct helmet-use rate could be caused by three factors: rate of nonuse, prevalence of cap helmets, and prevalence of unstrapped use. As illustrated in Table 2, the nonuse rate was relatively stable during the entire research period. The prevalence of unstrapped use more than tripled from 10.9 % in round 3 to 33.9% in round 8. That is the most significant contributor to the increasing rate of incorrect helmet use. The prevalence of cap helmets actually halved from 11.8 % to 5.9 % during rounds 3 − 8.

Fig. 3 illustrates the trends of four helmet-use behaviors across the eight rounds. The decline in the prevalence of strapped standard helmet use coincided with the increase in the unstrapped standard helmet use. The prevalence of nonuse and substandard helmet use had been relatively stable over time.

The multinomial model identified several individual and environmental factors affecting different types of helmet use (Table 4). The probability of wearing a strapped standard helmet was 11.3 percentage points higher for adults than for children while holding other individual and environmental factors constant (95 % CI: 10.5–12.1). The probability was 3.6 percentage points higher for drivers than passengers (95 % CI: 3.2–4.1). The probability declined by 22.4 percentage points from round 3 to round 8 (95 % CI: 21.8–23.0).

The comparison between nonuse and wearing an unstrapped standard helmet showed that being a driver and an adult was also associated with a higher probability of wearing an unstrapped standard helmet. That probability increased significantly over rounds. During rounds 3–8, the probability of wearing an unstrapped standard helmet increased by 24.5 (95 % CI: 24.1–24.9) percentage points.

The contrast between nonuse and wearing a substandard helmet shows a similar pattern. Being a female, a passenger, and an adult was associated with a higher probability of wearing a substandard helmet. The substandard helmet use by females had declined by 6.6 (95 % CI: 6.1–7.0) percentage points by round 8.

4. Discussion

To our knowledge, this study was one of the few multiyear repeated cross-sectional studies based on a city-level representative sample in Vietnam (Bao et al., 2017). While confirming the nearly universal helmet use found in previous studies, our results suggest a concerning downward trend for correct helmet use. The significant and increasing proportion of motorcycle riders wearing a substandard helmet or an unstrapped standard helmet presents an urgent issue for policymakers given the minimal protection provided by those incorrect helmet uses. Our results suggest that education campaigns were insufficient, and enforcement needs to be strengthened regarding the helmet quality and strapping requirements.

The study was not without limitations. First, our sample selection and observation plan might have missed some important points in time or location. It was challenging to conduct observations in heavily traveled areas where it was difficult to find a safe place for our observers. Also due to the safety concerns, our observation hours did not cover late in the evening or very early in the morning.

Second, although the purpose of the observational study was to measure and evaluate project performance, accurate attribution of the observed changes was too complex to accomplish. Since the launch of the BIGRS project in HCMC, local governmental agencies and other stakeholders were also conducting activities that could potentially affect helmet use. As a result, the complex nature of real-world interventions made it impossible to attribute the observed changes to any specific activities rigorously.

Third, the observational nature of the study limited the indicator choice and affected data quality. For example, in addition to cap helmets, many other helmets were also substandard, uncertified, and ineffective. Nevertheless, their differences from standard helmets were often too visually subtle to tell. Some indicators might be affected by an observer bias (e.g., age), though bias was unlikely substantial or systematic. The observer training for rounds 1–2 did not adequately emphasize the distinction between correct and incorrect helmet use, which might have led to misclassification in the first two rounds. We enhanced that component of the training after round 3, and the rate of unstrapped helmet use increased substantially in subsequent rounds. It is also worth noting that the downward trend between April 2017 and January 2018 was consistent with the previous and subsequent rounds. The enhanced training appeared to have affected the reduction rate without altering the direction of the change.

Despite the limitations, the consistent and substantial decline in correct helmet use over the eight rounds of data collection calls for urgent policy responses. Our data show two reasons for the declining rate for correct helmet use. The first reason was the increasing prevalence of unstrapped helmets. The laws explicitly required helmets to be strapped, but the enforcement was weak and awareness was low. Social marketing on the potential risks of not strapping helmets may be able to help.

The second reason was the use of substandard helmets. Although less prevalent, substandard helmet use also needs to be addressed due to its minimal effectiveness. The Vietnamese government has taken actions in

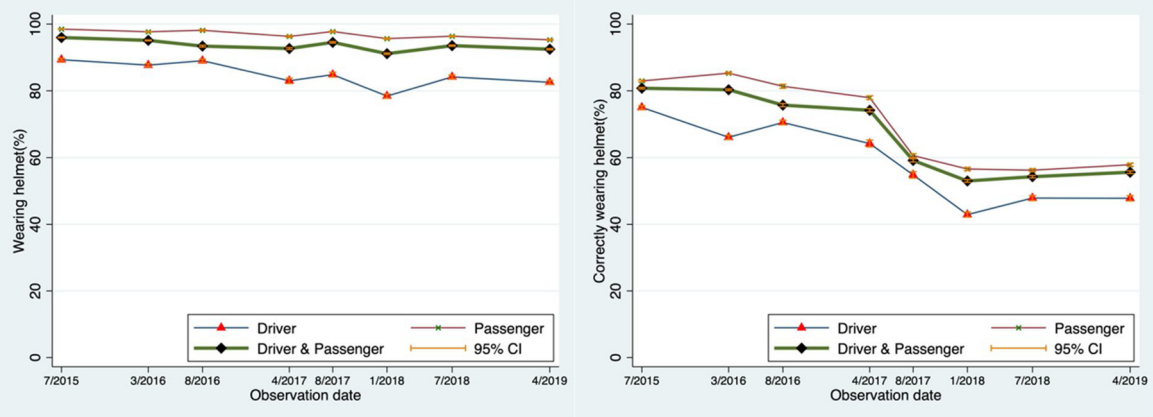

Fig. 2. Trend of Any Helmet Use (left) and Correct Helmet Use(right) for Motorcycle Riders in HCMC.

Table 3
Correct helmet-wearing rate by characteristics and by round in HCMC.

Characteristics	Round							
	1	2	3	4	5	6	7	8
Total	80.8	80.3	75.7	74.2	59.2	53.0	54.3	55.6
Sex								
Male	NA	NA	74.2	76.5	61.7	58.0	60.0	63.9
Female	NA	NA	77.6	70.9	55.5	45.5	45.4	41.7
User Type								
Driver	83.0	85.3	81.4	77.9	60.6	56.6	56.2	57.9
Passenger	75.0	66.1	70.5	64.2	54.8	42.9	47.9	47.8
Age								
< 18 years	NA	NA	69.8	49.8	43.1	27.0	32.1	34.7
> = 18 years	NA	NA	76.8	76.5	60.4	55.2	55.7	56.9
Weather								
Clear	NA	NA	75.3	74.1	58.5	53.0	54.9	55.6
Rainy	NA	NA	91.1	74.8	63.7	52.8	44.8	NA
Day of Week								
Weekday	79.9	80.5	75.7	74.3	57.6	53.3	52.8	55.2
Weekend	81.6	80.2	75.7	74.1	62.4	52.5	57.0	56.5
Time of Day								
Morning	80.4	80.5	77.4	72.9	58.5	52.8	53.5	57.2
Afternoon	80.1	80.4	74.3	74.4	59.6	51.9	54.2	50.1
Early Evening	82.2	80.1	73.9	75.9	59.7	55.1	56.0	63.0

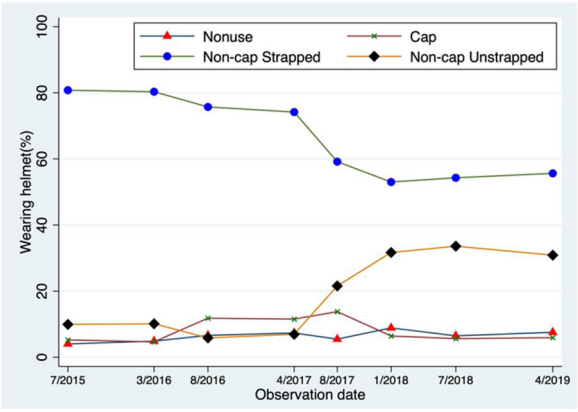

Fig. 3. Trend of Helmet-Wearing Behaviors for Motorcycle Riders in HCMC.

regulating helmet production and sale. As of May 2011, the Ministry of Industry and Trade of Vietnam has certified more than 400 types of helmet produced by about 80 manufacturers. However, substandard helmets, including baseball substandard-type helmets, are still prevalent in the market. Substandard helmets cost a fraction of that of certified helmets, and they are much lighter and more comfortable to wear. Restricting the production and sale of such substandard helmets is challenging because most vendors label them as caps rather than helmets. Police enforcement is also difficult because of the widespread use of substandard helmets.

Addressing improper wearing and substandard helmets requires an intervention package with multiple components and multisectoral involvement. The first component is raising and enforcing the helmet standard. An early study in 2008 found only 4.4 % of helmets in Vietnam met the mandated helmet standard (Hung et al., 2008). WHO and Hanoi School of Public Health surveyed 581 helmets in three Vietnamese provinces in 2012 (WHO and HSPH, 2012). Less than 20 % of the surveyed helmets withstood laboratory impact tests. Enforcing the standard includes regulating the production and sale of substandard helmets. Since low and affordable price is a major reason for riders to choose a substandard helmet, reducing the price for standard helmets through government subsidy or incentive may be helpful. Interviews of more than 400 households in Hanoi, Vietnam also suggest that helmet users are willing to pay a higher price for a standard helmet (Pham et al., 2008).

The second component is enhancing enforcement against substandard helmets. Innovative technologies may be helpful (Li et al., 2018). The third component is mass media campaigns that involve both print and electronic/social media to create dialogues between government and the general population that could potentially help riders to make informed decisions (Hill et al., 2009).

Our analyses also identified children and adolescents as the priority population for future interventions. Injuries account for 70 % of the burden of disease measured by the years of potential life lost (YLL) among the Vietnamese population under 18 years, which is much higher than the 17 % due to chronic diseases and 13 % due to communicable diseases (Linnan et al., 2003). Two rounds of survey assessment of Vietnamese youth found that over half of children and adolescents in Vietnam use motorcycles. The low helmet-use rate might help explain the high injury and fatality rate for this age group. Given the greater difficulty and additional challenge in enforcing helmet legislation among children than adults, an integrated approach is required. Incorrect beliefs, such as helmet weight increases children's risk of neck injuries, may have also attributed to the low helmet use among children (Pervin et al., 2009). An intervention study conducted in three large cities in Vietnam demonstrated that multisectoral interventions involving governments, civil society, and the corporate sector were effective in increasing helmet use among students (Nhan et al., 2019). The intervention activities included communications, school-based education, incentives for change, and police enforcement. Future interventions may also engage parents and other adults because children usually follow adults' example.

Vietnam is not unique in facing helmet use challenges. The use of substandard helmets and unstrapped helmets were also documented in

Table 4
Average marginal effects (AME) from the multinomial model of helmet wearing behaviors in HCMC.

Covariate	Substandard Helmet		Standard Helmet and Strapped		Standard Helmet and Unstrapped	
	AME	95 % CI	AME	95 % CI	AME	95 % CI
Sex (ref: female)						
Male	−0.017***	−0.019 - -0.015	0.110***	0.106 − 0.114	−0.120***	−0.123 - -0.117
Rider Type (ref: passenger)						
Driver	−0.005***	−0.008 - -0.003	0.036***	0.032 - 0.041	0.031***	0.027 − 0.034
Age (ref: < 18 years)						
> = 18 years	0.044***	0.041 - 0.047	0.113***	0.105 - 0.121	0.127***	0.122 − 0.133
Round (ref: 3)						
4	−0.008***	−0.013 - -0.002	−0.026***	−0.033 - -0.020	0.007***	0.003 - 0.011
5	0.011***	0.006 − 0.017	−0.176***	−0.183 - -0.170	0.148***	0.144 - 0.153
6	−0.061***	−0.065 - -0.056	−0.239***	−0.246 - -0.233	0.252***	0.247 - 0.256
7	−0.069***	−0.073 - -0.065	−0.232***	−0.238 - -0.226	0.268***	0.264 - 0.273
8	−0.066***	−0.070 - -0.061	−0.224***	−0.230 - -0.218	0.245***	0.241 − 0.249
Day (ref: weekend)						
Weekday	0.015***	0.013 − 0.017	−0.025***	−0.029 - -0.022	0.014***	0.010 − 0.017
Time (ref: morning)						
Afternoon	0.001	−0.002 - 0.003	−0.016***	−0.020 - -0.012	0.014***	0.011 − 0.018
Early Evening	0.001	−0.002 - 0.003	0.034***	0.030 − 0.039	−0.050***	−0.054 - -0.046
Weather (ref: rainy)						
Clear	−0.005**	−0.009 - -0.001	0.017***	0.010 − 0.024	−0.027***	−0.033 - -0.021
Observations	296,129					

Notes: *** p < 0.01, ** p < 0.05, * p < 0.1.

many other countries (Ambak et al., 2011; Wadhwaniya et al., 2015; Bachani et al., 2012). A study covering nine low- and middle-income countries found that nearly half of the helmets in those countries were substandard (Ackaah et al., 2013). It is typically more difficult to promote helmet-wearing for children than for adults (Dellinger and Kresnow, 2010; Fong et al., 2015). The shared challenges provide a cross-country learning opportunity.

In sum, our results from a five-year eight-round cross-sectional study send a rallying call for immediate actions to promote correct helmet use in Vietnam. Multisectoral responses are needed to convert current incorrect helmet users to correct users and to further increase the helmet use among children. Our results could be used to inform targeted intervention design and policy responses.

CRediT authorship contribution statement

Qingfeng Li: Conceptualization, Methodology, Data curation, Writing - original draft. **Oluwarantimi Adetunji:** Data curation, Writing - review & editing. **Cuong Pham Viet:** Data curation, Writing - review & editing. **Ngan Tran Thi:** Data curation, Writing - review & editing. **Edward Chan:** Data curation, Writing - review & editing. **Abdulgafoor M. Bachani:** Supervision, Writing - review & editing.

Appendix A

Tables A1 and A2

Table A1
Illustration of Correct and Incorrect Helmet0Wearing.

Helmet Wearing	Criteria	Illustrations
Correct wearing	- Right side - Quality helmet - Firmly strapped	
Incorrect wearing	- Unstrapped(topleft) - Wrong side (topright) - No strap (bottomleft) - Loosely strapped (bottomright)	

Table A2
Illustration of Three Major Helmet Types.

Helmet Type	Photo Example
Cap Helmet	
Tropical Helmet	
Full-face helmet	

References

Ackaah, W., Afukaar, F., Agyemang, W., et al., 2013. The use of non-standard motorcycle helmets in low- and middle-income countries: a multicentre study. Inj. Prev. 19 (3), 158–163.

Akaateba, M.A., Amoh-Gyimah, R., Yakubu, I., 2014. A cross-sectional observational study of helmet use among motorcyclists in Wa, Ghana. Accid. Anal. Prev. 64, 18–22.

Ambak, K., Ismail, R., Rahmat, R., Shokri, F., 2011. Do malaysian motorcyclists concern to safety helmet use? A cross-sectional survey. J. Appl. Sci. 11 (3), 555–560.

Bachani, A.M., Jessani, N.S., Pham, V.C., et al., 2013. Drinking & driving in Viet Nam: prevalence, knowledge, attitudes, and practices in two provinces. Injury 44 (Suppl 4), S38–44.

Bachani, A.M., Koradia, P., Herbert, H.K., et al., 2012. Road traffic injuries in Kenya: the health burden and risk factors in two districts. Traffic Inj. Prev. 13 (sup1), 24–30.

Bao, J., Bachani, A.M., Viet, C.P., Quang, N., Nguyen, N., Hyder, A.A., 2017. Trends in motorcycle helmet use in Vietnam: results from a four-year study. Public Health 144s, S39–s44.

Bhalla, K., Mohan, D., 2015. Safety of young children on motorized two-wheelers around the world: a review of the global epidemiological evidence. IATSS Res. 38 (2), 83–91.

Boyko, E.J., 2013. Observational research opportunities and limitations. J. Diabetes Complicat. 27 (6). https://doi.org/10.1016/j.jdiacomp.2013.07.007.

Dellinger, A.M., Kresnow, M.-j.-j., 2010. Bicycle helmet use among children in the United States: the effects of legislation, personal and household factors. J. Safety Res. 41 (4), 375–380.

Fong, M.C., Measelle, J.R., Dwyer, J.L., et al., 2015. Rates of motorcycle helmet use and reasons for non-use among adults and children in Luang Prabang, Lao People's Democratic Republic. BMC Public Health 15 (1), 970.

Ha, N.T., Ederer, D., Vo, V.A.H., et al., 2018. Chages in motorcycle-related injuries and deaths after mandatory motorcycle helmet law in a district of Vietnam. Traffic Inj. Prev. 19 (1), 75–80.

Hill, P.S., Ngo, A.D., Khuong, T.A., et al., 2009. Mandatory helmet legislation and the print media in Viet Nam. Accid. Anal. Prev. 41 (4), 789–797.

Hung, D.V., Stevenson, M.R., Ivers, R.Q., 2006. Prevalence of helmet use among motorcycle riders in Vietnam. Inj. Prev. 12 (6), 409–413.

Hung, D.V., Stevenson, M.R., Ivers, R.Q., 2008. Barriers to, and factors associated, with observed motorcycle helmet use in Vietnam. Accid. Anal. Prev. 40 (4), 1627–1633.

Ivers, R.Q., Nguyen, H.T., La, Q.N., 2014. Status of road safety and injury burden: Vietnam. J. Orthop. Trauma 28 (Suppl 1), S50–1.

Larson, K., Bavinger, R., Henning, K., 2016. The Bloomberg initiative for global road safety 2015-2019: addressing road traffic fatalities in low-and middle-income countries. J. Australas. Coll. Road Saf. 27 (3), 41.

Le, L.C., Blum, R.W., 2013. Road traffic injury among young people in Vietnam: evidence from two rounds of national adolescent health surveys, 2004-2009. Glob. Health Action 6, 1–9.

Li, Q., Peng, J., Chen, T., Yu, Y., Hyder, A.A., 2018. Seatbelt wearing rate in a Chinese city: results from multi-round cross-sectional studies. Accid. Anal. Prev. 121, 279–284.

Linnan, M., Pham, C., Le LC, Le P., Le, A., 2003. Report to UNICEF on the Vietnam Multi-Center Injury Survey. Hanoi School of Public Health, Hanoi.

Ngo, A.D., Rao, C., Phuong Hoa, N., Hoy, D.G., Thi Quynh Trang, K., Hill, P.S., 2012. Road traffic related mortality in Vietnam: evidence for policy from a national sample mortality surveillance system. BMC Public Health 12 (1), 561.

Nguyen, H., Ivers, R.Q., Jan, S., Martiniuk, A.L., Li, Q., Pham, C., 2013a. The economic burden of road traffic injuries: evidence from a provincial general hospital in Vietnam. Inj. Prev. 19 (2), 79–84.

Nguyen, H.T., Passmore, J., Cuong, P.V., Nguyen, N.P., 2013b. Measuring compliance with Viet Nam's mandatory motorcycle helmet legislation. Int. J. Inj. Contr. Saf. Promot. 20 (2), 192–196.

Nhan, L.D.T., Parker, L., Son, M.T.H., et al., 2019. Evaluation of an integrated multisector campaign to increase child helmet use in Vietnam. Inj. Prev. 25 (3), 206–210.

Olson, Z., Staples, J.A., Mock, C., et al., 2016. Helmet regulation in Vietnam: impact on health, equity and medical impoverishment. Inj. Prev. 22 (4), 233–238.

Passmore, J.W., Nguyen, L.H., Nguyen, N.P., Olivé, J.-M.-M., 2010. The formulation and implementation of a national helmet law: a case study from Viet Nam. Bull. World Health Organ. 88 (10), 783–787.

Pervin, A., Passmore, J., Sidik, M., McKinley, T., Nguyen, T.H.T., Nguyen, P.N., 2009. Viet Nam's mandatory motorcycle helmet law and its impact on children. Bull. World Health Organ. 87 (5), 369–373.

Pham, K.H., Le Thi, Q.X., Petrie, D.J., Adams, J., Doran, C.M., 2008. Households' willingness to pay for a motorcycle helmet in Hanoi, Vietnam. Appl. Health Econ. Health Policy 6 (2), 137–144.

Richards, P.G., 1984. Detachment of crash helmets during motorcycle accidents. Br. Med. J. (Clin. Res. Ed.) 288 (6419), 758.

Richter, M., Otte, D., Lehmann, U., et al., 2001. Head injury mechanisms in helmet-protected motorcyclists: prospective multicenter study. J. Trauma 51 (5), 949–958.

StataCorp, S., 2017. Statistical Software: Release 15.

Toroyan, T., 2007. Road traffic injury prevention receives boost from Bloomberg Family Foundation. Inj. Prev. 13 (6), 431-.

Wadhwaniya, S., Gupta, S., Tetali, S., Josyula, L.K., Gururaj, G., Hyder, A.A., 2015. The

validity of self-reported helmet use among motorcyclists in India. WHO South. Asia J. Public Health 4 (1), 38.
WHO, 2018. Global Status Report on Road Safety 2018. World Health Organization.
WHO, HSPH, 2012. Study on Motorcycle Helmet Quality in Viet Nam. World Health Organization and Hanoi School of Public Health.
Williams, R., 2012. Using the margins command to estimate and interpret adjusted predictions and marginal effects. Stata J. 12 (2), 308–331.
Wu, C., Yao, L., Zhang, K., 2012. The red-light running behavior of electric bike riders and cyclists at urban intersections in China: an observational study. Accid. Anal. Prev. 49, 186–192.
Yu, W.-Y., Chen, C.-Y., Chiu, W.-T.-T., Lin, M.-R.-R., 2011. Effectiveness of different types of motorcycle helmets and effects of their improper use on head injuries. Int. J. Epidemiol. 40 (3), 794–803.