



10 city analysis of child passenger helmet use

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ABSTRACT

Introduction: Road traffic injuries are the leading cause of death in children over age five. Most of these deaths occur in low- and middle-income countries. Vulnerable road users, such as motorcyclists and their passengers, are at higher risk. Helmets have significantly decreased morbidity and mortality for motorcyclists; however, they are often unused. The second phase of the Bloomberg Philanthropies Initiative for Global Road Safety was launched in 2015 to improve road safety in 10 cities. This study focuses on child passenger helmet use data from that study to understand the prevalence of helmet use and factors that are associated with helmet use.

Methods: The 10 cities selected were Accra, Addis Ababa, Bandung, Bangkok, Bogota, Fortaleza, Ho Chi Minh City, Mumbai, Sao Paulo, and Shanghai. Eight rounds of roadside observational data were collected from February 2015 to April 2019. Observers noted correct child motorcycle passenger helmet use and other site observations including weather patterns, traffic volume, and road surface conditions. A multivariable Poisson regression model was used to examine correct helmet use trends over time. A multivariable logistic regression model was fitted for correct child passenger helmet use in all cities controlling for weather, observation time, number of passengers, and driver's correct helmet use.

Results: This dataset contained 99,846 motorcycle child passenger observations across the 10 cities. The highest prevalence of correct child passenger helmet use was in Sao Paulo at 97.33%. Six cities had under 25% correct helmet use for child passengers. Examining helmet use over time, only five cities had a significant increase, four cities had no change, and Ho Chi Minh City demonstrated a decrease. In the multivariable regression model, child passengers had higher odds of wearing helmets in adverse weather conditions, early mornings, if the driver wore a helmet, and if there were fewer passengers.

Conclusions: The prevalence of correct child passenger helmet utilization shows large variation globally and is concerning low overall. Enhanced enforcement in combination with media campaigns may have contributed to increasing helmet use prevalence over time. Further research is needed to understand reasons for low child passenger helmet use in most cities.

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Introduction

Road traffic injuries (RTI) are a growing and serious public health problem for children worldwide. RTI is the leading cause of death in children over 5 years of age [1]. The worldwide distribution of these deaths is not equal, with 90% of road traffic deaths

occurring in low- and middle-income countries (LMICs) [2]. The death rate is three times higher in low-income countries compared to high-income countries. To achieve the Stockholm Declaration of halving the number of road traffic deaths by 2030 and Sustainable Development Goal 11.2 to provide safe transport systems, particularly for vulnerable individuals, drastic action needs to be taken in LMICs [1,3].

The most vulnerable road users are pedestrians, cyclists, and drivers and passengers of two- and three-wheeled motorcycles. More than half of all road traffic deaths occur in this population [1]. For motorcyclists, road traffic deaths are an increasing problem as the number of two- and three-wheeled motorcycles increases on the world's roads annually. In several countries, mo-

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motorcycles make up the majority of all national vehicles [1]. To reduce deaths for motorcyclists and passengers, the single most effective way is to increase proper helmet use, as most deaths are related to head injuries [4]. Proper helmet use has been shown to reduce the risk of fatal injuries by 42% [5]. Unfortunately, in 175 countries surveyed by the WHO, only 49 have laws that meet best practice criteria, which include laws pertaining to drivers and passengers, all road and engine types, specifying helmets need to be fastened, and helmet standards [1]. To again demonstrate the disparity with low-income countries, only 6% of countries with best practice laws are low-income countries [1]. Reduced helmet wearing in children compared to adults is a serious issue demonstrated in multiple studies [6–8].

Increasing helmet use is challenging and it is clear from the literature that a comprehensive strategy that includes legislation, enforcement, and media campaigns is needed for significant and sustained changes [9,10]. Furthermore, minimum age requirements have also been advocated for [11,12], as well as improving affordability of helmets [12]. One of the first steps to advocate for national change is to raise awareness about the issue and show comparisons. In 2007, Bloomberg Philanthropies launched the Initiative for Global Road Safety (BIGRS). This was an international collaboration with the goal of improving road safety. The second phase of the project, which started in 2015, focused on addressing road safety in 10 cities: Accra, Addis Ababa, Bandung, Bangkok, Bogota, Fortaleza, Ho Chi Minh City, Mumbai, Sao Paulo, and Shanghai. This multifaceted project included enforcement strengthening, infrastructure improvements, policy development and implementation support, and promotion of road safety best practices [7]. The purpose of this study is multifold. First, we want to examine the overall prevalence of child passenger helmet use in each of the 10 cities. Second, we want to explore how this prevalence has changed over time during the four-year study period. Finally, we will investigate factors associated with correct child passenger helmet use in the dataset.

Methods

Study design

A standardized protocol was used for helmet observations in all 10 cities. Data was collected in eight rounds from February 2015 to April 2019. To obtain a representative sample of local traffic patterns, six observational sites were selected using a systematic sampling approach in each city, which included urban divisions (typically paved/tarmac), peri-urban divisions (may be paved or unpaved), and city administrative divisions. All locations chosen were at junctions or intersections and met the following criteria: a) safe for the observer, b) a location where the observers may be located at an elevation that was higher than or equal height of the motorcycle, and c) a location where the local population, rather than tourists, are likely to be observed.

During each round, each site recorded observations for three full days. These three days consisted of two weekdays and one weekend day. Where resources were available, a fourth observation day was added. Each day consisted of observations from 06:30 to 19:30, broken down into 90-minute times where motorcycles were recorded. Only motorcycles and scooters were included, while mopeds and e-bikes were excluded. Two trained field workers completed each observation period with one person observing and the other recording. Traffic was only recorded in one direction of flow to minimize double counting and improve accuracy in high traffic areas. If there were two motorcycles passing the observer at the same time, they were instructed to record the motorcycle that was closest to the curb and observer. Each field worker underwent

comprehensive training and practice prior to field work and had close supervision to ensure the quality of the data.

Field workers visually estimated the age and sex of each motorcycle driver and passenger. A child was defined as a person appearing to be under 18 years of age. For the specific type of helmet, observers made a distinction between full-face helmets, non-full-face helmets, and cap helmets. They also noted whether the helmet was strapped or unstrapped. Site observations included weather patterns, traffic volume, and road surface conditions. This observational methodology has been previously used in other road safety studies [7,13–17].

Correct helmet use was defined as a child wearing either a full-face or non-full-face helmet that was strapped. A cap helmet, even if strapped, was not classified as correct helmet use. See Fig. 1.

Statistical analysis

The data for this study was analyzed using StataMP 16 and the outcome of interest was the prevalence of correct helmet use among child passengers [18]. First, exploratory data analysis was done to identify trends in helmet use among passengers in the 10 cities, with special attention given to helmet use among child passengers in each city across the eight rounds of data collection. Of note, child passenger observations were excluded if the helmet use status or the type of helmet used were missing. The characteristics of the child passengers were established through tabulations focusing on the following factors: correct helmet use, whether the driver of the motorcycle wore a helmet, the total number of passengers and the total number of children on the motorcycle, and the day and time of the observation. Tabulations were also used to identify the prevalence (by round and overall) of a lack of helmet use, strapped or unstrapped, cap helmets, and correct helmet use among child passengers in each city. The overall prevalence in each city has been presented in this paper for ease of interpretation and presentation of the data.

Next, the data for each city was examined using robust Poisson regression [19] models to assess changes in child passenger helmet use over time. Bivariable and multivariable analyses were used, with the bivariable analyses examining the prevalence of the use of correct child passenger helmet across the eight rounds for each city and the multivariable analyses including the added variables of weather and observation time. For the initial analyses, each variable was categorical. Correct child passenger helmet use was dichotomous, while round was established as a continuous variable. The observation time was categorized as 06:30–09:59, 10:00–12:59, 13:00–15:59 and 16:00–19:30. The Poisson goodness-of-fit test was used to confirm the appropriateness of the models.

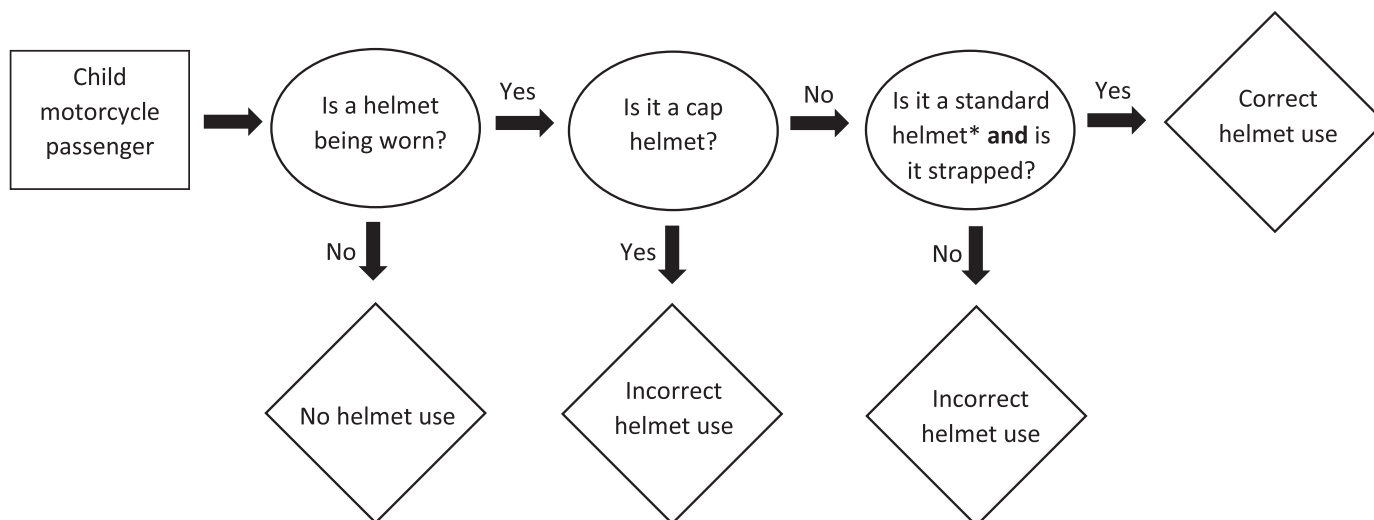
To assess factors associated with child passenger motorcycle helmet use, a multivariable logistic regression model was fitted for the correct child passenger helmet use in all cities. We controlled for weather (categorical), observation time (categorical), number of passengers (continuous), and the driver's use of a correct helmet (categorical).

Ethics approval

This study received approval from the Institutional Review Board at the Johns Hopkins Bloomberg School of Public Health, USA. All local partners in each city also received Institutional Review Board approval.

Results

Over four years from February 2015 to April 2019, we recorded observations for a total of 2,121,516 unique motorcycle observations across 10 cities and eight rounds of data collection. The ma-



*A standard helmet is defined as a full-face or non-full-face helmet

Fig. 1. Helmet use definition

*A standard helmet is defined as a full-face or non-full-face helmet.

Table 1
Features of all passengers observed.

City (n)*	Overall passenger correct helmet use [%] (n)**	Percent of passengers that were children [%] (n)***
Accra (47,606)	32.06 (15,258)	2.18 (1040)
Addis Ababa (10,984)	5.56 (610)	4.36 (479)
Bandung (134,196)	45.56 (61,078)	28.54 (38,042)
Bangkok (124,318)	22.62 (28,014)	15.65 (19,268)
Bogota (24,063)	84.93 (20,355)	5.95 (1428)
Fortaleza (67,891)	82.26 (55,749)	4.35 (2948)
Ho Chi Minh City (81,460)	49.05 (39,929)	24.25 (19,722)
Mumbai (106,418)	0.41 (438)	12.52 (13,249)
Sao Paulo (8532)	98.01 (8362)	3.52 (300)
Shanghai (12,439)	2.91 (362)	30.49 (3786)

*n= total number of passengers observed in each city.

**Total n: 616,795 (excludes 1112 individuals with missing data on correct helmet use).

***Total n: 614,977 (excludes 2930 individuals with missing data on age).

Table 2
Characteristics of 99,846 child passengers.

Variable	Correct helmet use
Overall,%	19.83
Driver of motorcycle wearing helmet,%	
Yes	30.25
No	6.08
Total children on each motorcycle,%	
One child	22.04
Two or more children	12.07
Day of week,%	
Sunday	16.44
Monday	24.80
Tuesday	21.37
Wednesday	17.96
Thursday	16.14
Friday	14.20
Saturday	28.55
Time of day,%	
06:30–9:59	21.01
10:00–12:59	17.14
13:00–15:59	21.09
16:00–19:30	19.42

majority of these motorcycles (1,548,678) had drivers only. The remaining 572,838 motorcycles had at least one passenger and, of these, 88,843 had at least one child passenger. In total we observed

100,262 child passengers and, after excluding 416 child passenger observations due to missing data, the final dataset included 99,846 motorcycle child passengers. See Fig. 2. The mean number of child passengers on the motorcycles included in the final dataset was 1.31 (SD 0.55).

For all 616,795 passengers, including both adults and children, the prevalence of correct passenger helmet use ranged from 0.41% in Mumbai to 98.01% in Sao Paulo. The percentage of the passengers that were children ranged from 2.18% in Accra to 30.49% in Shanghai. See Table 1.

The overall percentage of correct helmet use among the 99,846 child passengers across all cities was low, at 19.83%. Correct helmet use was higher, 30.25%, if the driver was wearing a helmet, compared to 6.08% if the driver was not wearing a helmet. Correct helmet use was also higher with one child passenger compared to two or more, on certain days of the week, and at certain time periods during the day. See Table 2. Among the 10 cities, there was wide variation in child passenger helmet use. The prevalence of child passengers not wearing a helmet was highest in Mumbai (99.46%), Shanghai (98.20%), and Addis Ababa (91.02%), and lowest in Bogota (2.73%) and Sao Paulo (0.33%). Cap helmet use was highest in Bangkok (10.11%). Sao Paulo had the highest prevalence of correct child passenger helmet use (97.33%), and Mumbai had the lowest (0.33%). Six of the 10 cities in this analysis had less than 25% cor-

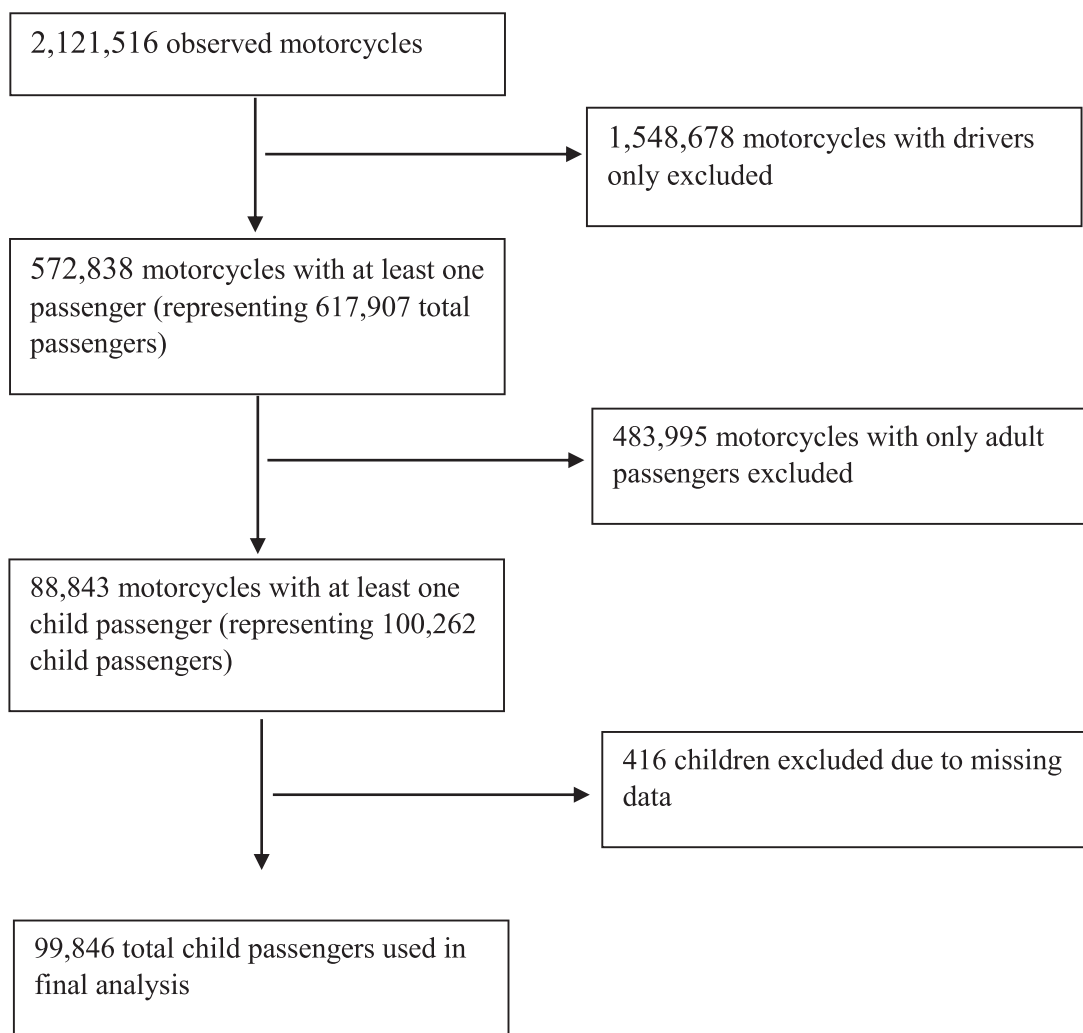


Fig. 2. flowchart of child passenger selection.

Table 3 Overall prevalence of child passenger helmet use in 10 cities.

City (n)	Prevalence no helmet [%] (n)	Prevalence strapped helmet use [%] (n)	Prevalence unstrapped helmets [%] (n)	Prevalence cap helmet use [%] (n)	Correct helmet use [%] (n)
Accra (1039)	77.96 (810)	20.31 (211)	1.73 (18)	3.08 (32)	17.13 (178)
Addis Ababa (479)	91.02 (436)	5.01 (24)	3.97 (19)	2.51 (12)	4.18 (20)
Bandung (38,010)	71.32 (27,108)	20.81 (7909)	7.87 (2993)	0.57 (217)	20.32 (7724)
Bangkok (19,086)	83.49 (15,935)	15.84 (3023)	0.67 (128)	10.11 (1929)	6.01 (1147)
Bogota (1426)	2.73 (39)	81.63 (1164)	15.64 (223)	1.26 (18)	80.58 (1149)
Fortaleza (2931)	20.98 (615)	63.66 (1866)	15.35 (450)	0.38 (11)	63.39 (1858)
Ho Chi Minh City (19,633)	47.46 (9318)	39.62 (7779)	12.92 (2536)	4.56 (895)	37.32 (7328)
Mumbai (13,156)	99.46 (13,085)	0.43 (56)	0.11 (15)	0.08 (10)	0.33 (43)
Sao Paulo (300)	0.33 (1)	98.00 (294)	1.67 (5)	0.67 (2)	97.33 (292)
Shanghai (3786)	98.20 (3718)	1.77 (67)	0.03 (1)	0.21 (8)	1.56 (59)

Total n: 99,846.

rect helmet use for child passengers, including Accra, Addis Ababa, Bandung, Bangkok, Mumbai, and Shanghai. See Table 3.

Four of the 10 cities did not demonstrate changes in correct child passenger helmet use over time. In the Poisson regression, no significant change in child passenger helmet use was observed in Accra, Bogota, Sao Paulo, or Shanghai during the study period. Helmet use significantly increased in Addis Ababa, Bandung, Bangkok, Fortaleza, and Mumbai, while in Ho Chi Minh City, a significant decrease was observed. See Table 4. In the multivariable logistic

regression model, child passengers had higher odds of wearing a helmet in light or heavy rain and fog compared to dry conditions. Compared to the earliest time of day, between 06:30 and 10:00, child passengers were significantly less likely to have correct helmet use around midday. With an increasing number of passengers on a motorcycle, child passengers were also less likely to be wearing a helmet correctly. Most significantly, children had an odds ratio of 7.477 for correct helmet use if the driver was also wearing a helmet. See Table 5.

Table 4
Prevalence ratio of correct helmet use among child passengers in each city per round (Total n = 99,846).

City	Prevalence Ratio (SE)	
	Bivariate	Multivariable
Accra (n = 1039)	0.981 (0.030)	1.003 (0.032)
Addis Ababa (n = 479)	1.318** (0.131)	1.308** (0.129)
Bandung (n = 38,010)	1.043*** (0.006)	1.043*** (0.006)
Bangkok (n = 19,086)	1.045 ** (0.017)	1.049 ** (0.017)
Bogota (n = 1426)	1.003 (0.006)	1.005 (0.006)
Fortaleza (n = 2931)	1.055*** (0.006)	1.054*** (0.006)
Ho Chi Minh City (n = 19,633)	0.890 *** (0.005)	0.888 *** (0.005)
Mumbai (n = 13,156)	1.159** (0.077)	1.182** (0.079)
Sao Paulo (n = 300)	0.993 (0.005)	0.994 (0.005)
Shanghai (n = 3786)	1.00 (0.059)	1.101 (0.090)

Multivariable models controlled for weather and observation start time. As a result of collinearity, weather was omitted for Bangkok and Shanghai. *P < 0.1; **P < 0.05; ***, P < 0.001.

Table 5
Results of multivariable logistic regression model for correct child passenger helmet use in all cities (Total n = 99,846).

Variable	OR (SE)
Weather condition	
Dry/no rain	Ref
Light rain	1.424*** (0.060)
Heavy rain	1.291*** (0.083)
Fog	1.277* (0.172)
Other	0.456 (0.221)
Observation start time	
6:30 AM-<10 AM	Ref
10AM -<1PM	0.841*** (0.020)
1 PM -<4PM	0.992 (0.023)
4 PM-7:30PM	0.975 (0.023)
No. of passengers	0.376*** (0.006)
Correct driver helmet	7.477*** (0.169)

*P < 0.1; **P < 0.05; ***, P < 0.001.

Discussion

To our knowledge, this is the largest study of child passenger helmet use to date, encompassing four years of data collection across 10 cities in nine countries. The prevalence of correct helmet utilization shows large variation and is concerning low overall at 19.83%. What is even more concerning is that only five cities demonstrated an increase in child passenger helmet use over time, while four cities showed no change and Ho Chi Minh City showed a decrease. A decrease in child passenger helmet use has also been demonstrated previously in a different region of Vietnam [17]. These results suggest that a much greater effort in legislation, enforcement, and educational campaigns are needed to protect children, especially in areas with no improvement. Lessons learned from cities with a high prevalence of child passenger helmet use may also be helpful.

During the study period, several road traffic safety interventions were initiated at various time periods in each of the 10 cities, but not all were related to helmet use. It is possible that these interventions contributed to improved child passenger helmet use. Nine of the ten cities had some type of new helmet use intervention. The only city that did not was Sao Paulo, which has regular enforcement and the highest prevalence of correct child passenger helmet use. Of the nine cities that implemented a helmet related road safety intervention, six had enhanced enforcement (Accra, Addis Ababa, Bandung, Bogota, Fortaleza, Mumbai) and seven had media campaigns (Bandung, Bangkok, Bogota, Fortaleza, Ho Chi Minh City, Mumbai, Shanghai). Three of the four cities that had both enhanced enforcement and media campaigns (Bandung, Fortaleza, Mumbai) demonstrated increased child passenger hel-

met use over the study period. The fourth city, Bogota, already had relatively high child passenger helmet use and did not show a decrease. These interventions highlight the importance of a multi-pronged, ongoing approach to improve child passenger helmet use.

Multiple studies from both HICs and LMICs have shown the devastating impact that helmet non-use has on children [1,20–22]. Despite this, helmet use remains unacceptably low in many LMICs and many countries still do not meet WHO best practice guidelines for helmet legislation. In our study, only five of nine countries met these standards. Four countries, Ethiopia, Indonesia, Colombia, and China, did not require helmets to be fastened during the study period. In addition, in Ethiopia, helmet legislation does not specify or refer to a standard [1]. Although progress has been slow, it is promising that countries are improving their helmet laws. In Colombia, for example, it is now the law that all motorcycle riders have strapped full face helmets as of 2021. Broad legislation encompassing child passengers is an important first step in ensuring the protection of children. A recent systematic review including articles from both HICs and LMICs found that helmet legislation was associated with decreased road traffic-related injuries and fatalities among motorcyclists [23]. Excess injuries and deaths due to lack of helmet laws have also been shown to increase health care costs [24], and motorcycle helmet use saves disability-adjusted life years (DALYs) [25]. It is estimated in Vietnam that a comprehensive helmet policy would save \$11,000 per death averted and \$830 per non-fatal injury averted [26]. Legislation alone, however, does not consistently ensure increased helmet use, especially in LMICs [27,28], likely due to other factors such as enforcement and public knowledge.

Helmet use enforcement is critical to the uptake of helmet use but challenging to measure. The 2018 WHO Global Status Report on Road Safety utilized a 10-point rating system where countries would report their enforcement. Of the countries in our study, Ethiopia rated their enforcement the lowest at 2/10, while Indonesia rated their enforcement the highest at 9/10. Of note, Bandung, Indonesia had a correct child passenger helmet utilization rate of less than 20%, highlighting the difficulty of enforcement measurement. Despite the challenges, it is critical that the countries focus on enforcement of helmet laws as this has been shown to increase helmet use in several LMICs including Vietnam and Uganda [29]. Child passengers have also been shown to have increased odds of helmet use if adult drivers are wearing helmets [15,30]. While enforcement is improved, it is critical to focus on vulnerable road users such as child passengers, as adults have shown greater increase in helmet use than children with increased enforcement in Thailand [31]. Experience from the Global Helmet Vaccine Initiative has shown that programs targeting at-risk motorcyclists such as child passengers can result in the public support needed for decision-makers to act [29]. Nhan et al. demonstrated that targeted public awareness, enhanced enforcement and capacity building to support government departments can result in a sustained increase in child passenger helmet use [32].

The literature shows that drivers consistently wear helmets at substantially higher rates than adult and child passengers [6–8,22,27,30,33–37]. Roadside surveys in Cambodia and Kenya noted that the primary reason for helmet use among drivers was that they understood the life-saving potential of a helmet [27,28,35]. When asked about child passenger use, drivers in multiple countries reported that the main reason to not secure a helmet on their children was that they were “too young” or there was no need [8,17,36,38]. This is a dangerous misconception as it has been shown that younger children are more likely to suffer head injuries when injured as motorcycle passengers [11,22], and that, for children under 16, a head injury is more likely to result in a fatality compared to other injuries [39]. Another myth is that helmets can cause neck injuries in young children [17], which is not true [12].

In Bogota, it is illegal to transport any child under the age of 10 on a motorcycle. This could be a reason why Bogota has a relatively high child passenger helmet use rate compared to other cities, as parents would not have these misconceptions about older children.

Another issue is that of non-standard helmets, which are known to have widespread use in LMICs [40], despite the fact that there are international guidelines and standards [12]. In our study, these substandard helmets were identified as “cap” helmets, but it is certainly possible that other helmets observed did not meet safety standards. In Ethiopia, for example, there is no standard referred to in the legislation [1], and not every LMIC has specific legislation to prohibit the sale of non-standard helmets [40]. The reduced cost of non-standard helmets was the most significant reason for their use [40], but, importantly, cost should not compromise quality [12]. Substandard use of child helmets has been shown to be as high as 13.7% in regions in Vietnam [17]. In line with the use of substandard helmets, some motorcyclists may not have helmets at all for their children. In studies from Cambodia [35] and Kenya [27], the majority of motorcycle drivers did report owning a helmet, but in one study from China, 70% of parents did not have a helmet for their child [38]. These studies underscore the need for low-cost, age-appropriate, standardized helmets to ensure children are protected.

This study has several limitations common to roadside observational studies. First, the age of the passengers was based on a subjective assessment made by assessors and it is possible they over- or underestimated the true child population. Second, it was not possible to accurately determine if the helmet worn met any type of safety standard, although we were able to identify cap helmets as clearly substandard. Third, observation locations and data collection time periods had to be selected with consideration for the safety of observers, so it is possible that there were important time or location data points that were missed.

Conclusion

This study represents the largest multi-country dataset of child passenger helmet use from 10 cities over a period of four years. Overall, the helmet use rate is unacceptably low in nearly all the cities, with the exception of Sao Paulo and Bogota. In cities without high child passenger helmet use, the combination of enhanced enforcement and media campaigns may have contributed to increasing helmet use prevalence over the study period. Future research should look specifically at underlying reasons for low helmet use in children to understand parental knowledge, attitudes, and practices. There is also a need to assess the availability of standardized, age-appropriate helmets, and any policy gaps that may exist.

Declaration of Competing Interest

None to declare.

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