Impact response of motorcycle helmets in low-, mid-, and high-income countries

Erin Rodenberger, Bridget Shaia, Jeff Crandall, Kavi Bhalla, Nathan Scott

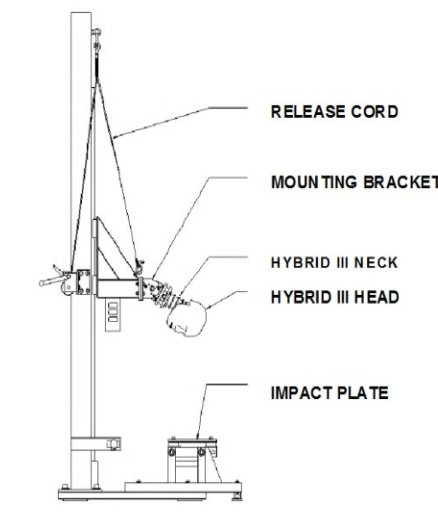
Introduction

In the United States, the percentage of traffic fatalities due to motorcycle crashes is 5-18%;[1] in low- and middle-income countries these rates are much higher, 70-90% in Thailand.[2] The main cause of death in these crashes are head and neck injuries. Motorcycle helmets protect drivers and riders from fatality and head injury. Internationally, various safety certifications exist to regulate the protective ability of helmets, including the U.S. Department of Transportation (DOT) FMVSS 218. However, a survey of low-and middle-income countries showed that 49% of motorcycle riders wear uncertified helmets, and that some of these helmets are not even designed for motorcycle use.[3] The uncertified helmets are typically more affordable, more comfortable, and more aesthetic for the riders.

Objective

To date, no study has compared the performance of certified and uncertified helmets from multiple countries. This study aims to analyze the performance of various helmets with respect to their certification and country of origin.

Methods



- Test location and impact severity of the helmet testing was comparable to the DOT FMVSS 218 Motorcycle Helmet Safety Standard
- Helmeted Hybrid-III head and neck was mounted to a drop tower and released from a height of 2 meters to produce a 6m/s impact speed
- Helmets were fitted snugly to the head and neck and the chin strap was tightened as secure as possible
- Each helmet was impacted 6 times: twice on the front, twice on the rear, and twice on the side
- Impact speed, impact forces, helmet mass, padding thickness, linear accelerations and angular rates at the head center of gravity were measured
- Data was filtered at CFC 1000 and peak linear acceleration, HIC[4], peak rotational velocity, and BrIC[5] were calculated

$$HIC = \left\{\left[\frac{1}{t_2 - t_1}\int_{t_1}^{t_2} a(t)dt\right]^{2.5} (t_2 - t_1)\right\}_{max}$$

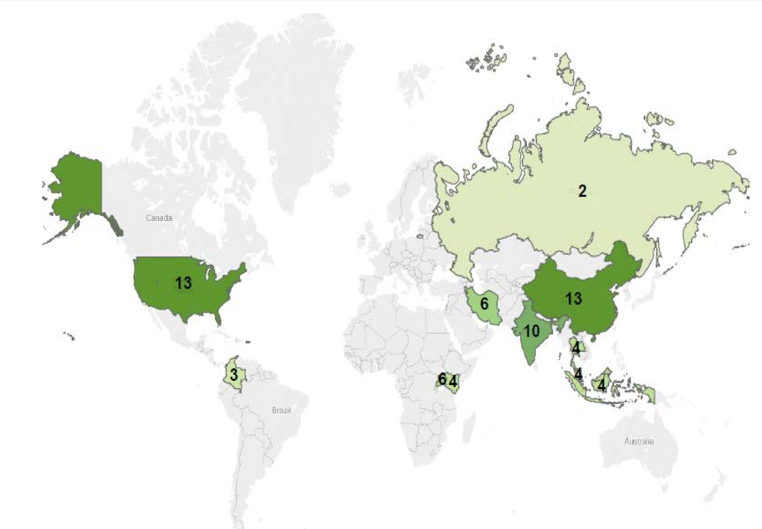
where a(t) is the resultant linear acceleration and t_1 - t_2 < 15 ms

$$BrIC = \sqrt{\left(\frac{\omega_x}{\omega_{xc}}\right)^2 + \left(\frac{\omega_y}{\omega_{yc}}\right)^2 + \left(\frac{\omega_z}{\omega_{zc}}\right)^2}$$

where ω_i are maximum angular velocities and ω_{ic} are the critical angular velocities (ω_{xc} = 66.25, ω_{yc} = 56.45, ω_{zc} = 42.87)

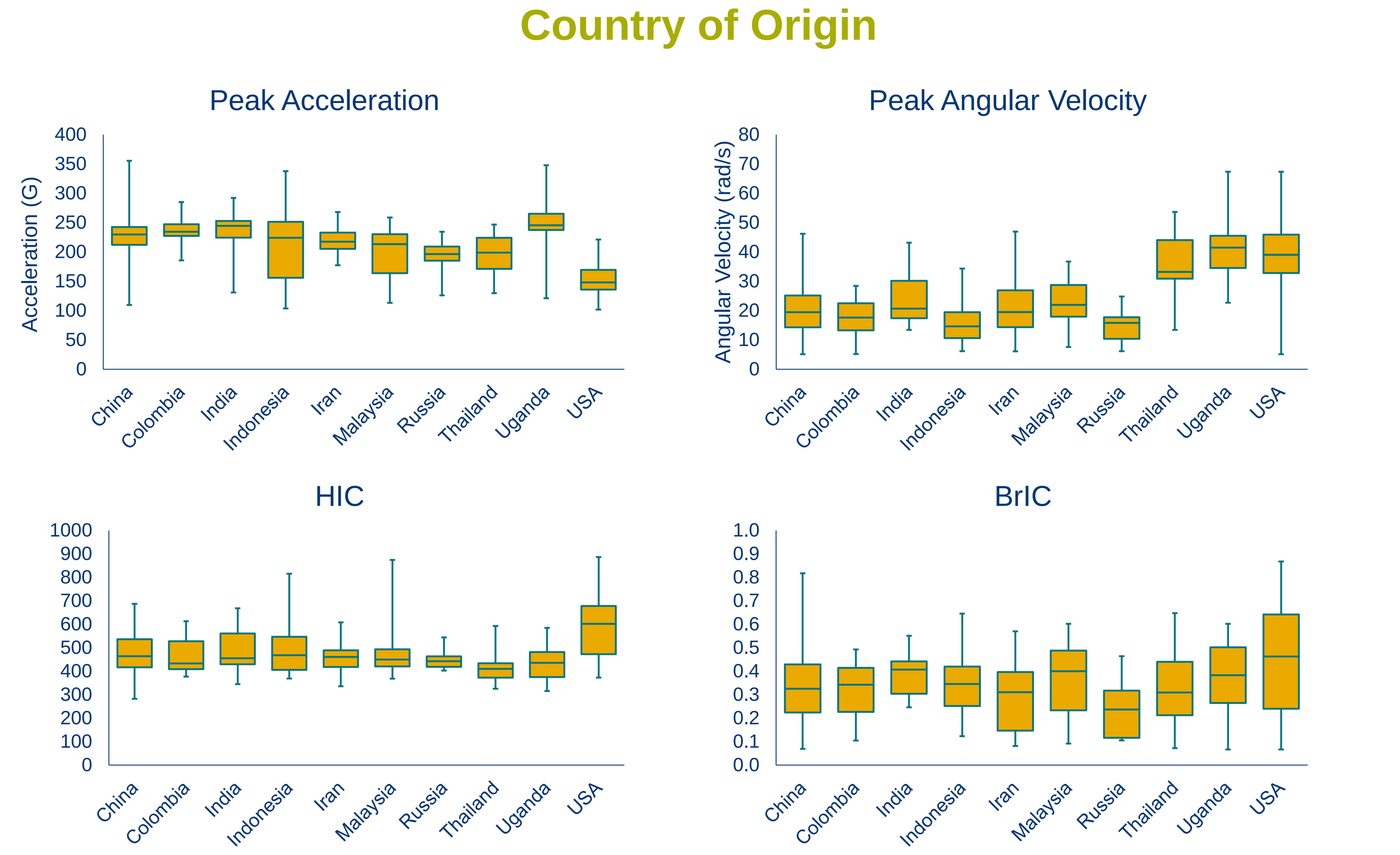
- Results were analyzed using a linear regression using categorical predictors for country, impact location and helmet certification

Results

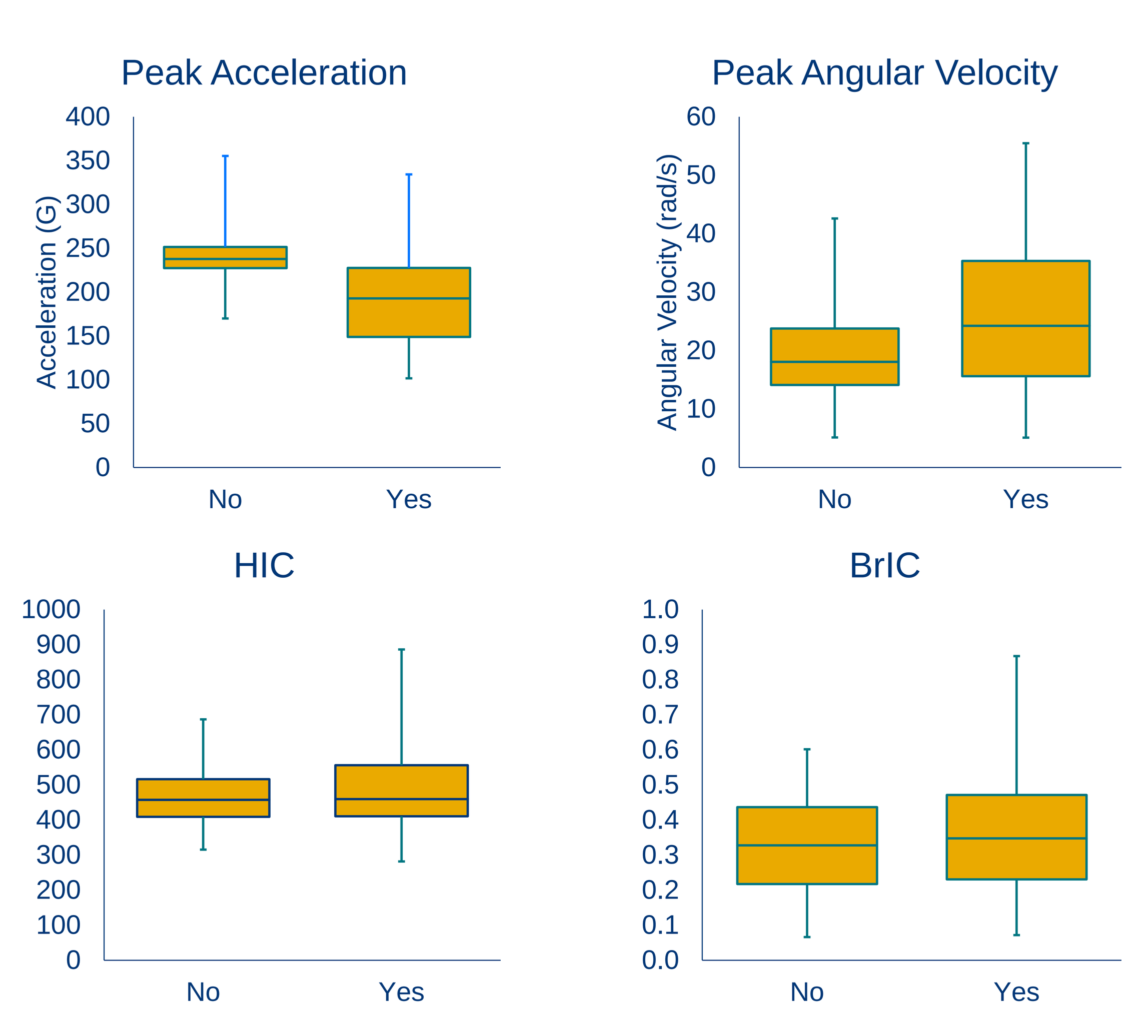


- Fifty-five helmets from the United States, Russia, China, India, Kenya, Colombia, Indonesia, Iran, Malaysia, Thailand, and Uganda were tested for a total of 298 tests
  - 8 helmets sustained major damage and were unable to complete all 6 impacts
- Peak linear accelerations ranged from 101.7 G to 355.3 G and HIC values were between 282 $G^{2.5}$s and 886 $G^{2.5}$s
- Peak angular velocities fell between 5.11 to 67.36 rad/s and BrIC values ranged from 0.07 to 0.87
- Significant statistical analysis results are as follows:

Country of Origin



Certification



Discussion + Conclusion

- Country of origin was found to have a rather large and significant effect on for all four parameters of interest ($p < 0.001$).
- Certified helmets only outperformed uncertified helmets in peak linear acceleration, and this difference was significant ($p < 0.001$). For the other three parameters of interest, both groups performed about evenly.
- The type of helmet (full face, open face, or half) had little effect on the helmet's impact response.
- Compared to DOT FMVSS 218 safety requirements, no helmets failed. However 8 helmets (7 uncertified, 1 certified) sustained major damage and could not complete testing. It is assumed that the riders would not wear helmets with major damage
- These tests used a Hybrid III head and neck, while the DOT standard require a magnesium head form. The difference in these head forms means that there may not be a direct comparison between this study and the standard. Data within this test set can be used to compare one helmet to another, so conclusions still may be drawn based on performance
- The average certified helmets price was 2.5 times more expensive than the uncertified helmets ($28.55 compared to $11.09)
- This study shows that uncertified helmets have HIC and BrIC values comparable to certified helmets. However, peak acceleration is significantly higher in uncertified helmets, meaning certified helmets may be slightly more protective than uncertified helmets.

[1] Mohan, D. (2002). Traffic safety and health in Indian cities. *Journal of Transport and Infrastructure*, 9:79–94.
[2] Suriyawongpaisal, P., & Kanchanusut, S. (2003). Road traffic injuries in Thailand: trends, selected underlying determinants and status of intervention. *Injury Control and Safety Promotion*, 10:95–104.
[3] Ackaah, W et al. (2013). The use of non-standard motorcycle helmets in low- and middle-income countries: A multicenter study. *Injury prevention, 19(3),* 158-163.
[4] Versace, John. "A Review of the Severity Index." SAE Technical Paper, 1971.
[5] Takhounts, E. G., Craig Matthew J Craig, K Moorhouse, J McFadden, and V Hasija. "Development of Brain Injury Criteria (BrIC)." *Stapp Car Crash Journal* 57 (2013): 243–66.

University of Virginia Engineering
Johns Hopkins Bloomberg School of Public Health

Erin Rodenberger, ejr4ef@virginia.edu
4040 Lewis and Clark Drive
Charlottesville, VA 22911