

age) were significant and demonstrated reasonably high R^2 for SAT depths at ASIS, perimeter, and diametric lengths. This indicates that the greater the BMI of the occupant, particular attention should be paid to the amount of SAT around the pelvis.

The data from this study can be used in efforts to narrow the gap in outcomes by sex in the implementation and design of passive safety systems. Recent studies have noted that disparities exist between outcomes from crash for male and female occupants (Forman et al. 2019). While data is presented in a single plane and posture, established landmark-based morphing techniques can make use of sparse data for morphing targets, and can be used to modify the soft tissue envelope of surrogate models to match these observed values. A limitation to this study is that all data were collected in supine posture. Future work should investigate how these data change with posture using imaging modalities that allow varying postures, such as upright MRI.

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Influence of certification in the impact response of motorcycle helmets: A multicountry study

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Introduction

Motorcycle users comprise a significantly sizable percentage of fatalities globally (World Health Organization 2019), which has increased steadily in recent years. For instance, motorcycle rider deaths reported in China increased 6-fold between 2004 and 2010 (Zhang et al. 2015). Although most motorcyclist deaths occur in low- and middle-income countries (LMICs), they account for a substantial number of deaths in high-income countries, too: about 4,000 motorcyclists were killed in the European Union in 2019, accounting

for 18% of all motor vehicle fatalities (European Commission 2021). The vulnerability of motorcycle users is particularly worrisome because there has been a large growth of motorcycles in the vehicle fleets in many countries. For example, in Iran it grew 5-fold between 2000 and 2005 (Bhalla et al. 2009) and in Brazil it grew 4-fold between 1995 and 2005 (Bhalla et al. 2010).

Motorcycle riders face one of the highest relative risks of all road users primarily because of the lack of protection of the human body during a crash (Lin and Kraus 2009).

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Motorcycle helmets, popularized in the 1950s, have been shown to be one of the most effective methods to reduce the injury risk to motorcycle riders. A systematic review (Liu et al. 2008) found that helmets reduce the risk of head injury by around 69% and the risk of death by 42%. As a result, many national and international agencies have large ongoing programs to encourage and enforce helmet use in LMICs (World Health Organization 2019).

The propagation of helmets has led to the establishment of certification procedures aiming to standardize product quality and to certify that the helmets provide a minimum level of head protection. For instance, United Nations Economic Commission for Europe (UNECE) Reg. 22 is a widely recognized international certification protocol and 47 countries have committed to it since it came into force in 1982 (ECE 22-06 2021). But multiple certification programs co-exist in different countries, including, for example U.S. Department of Transportation (USDOT) FMVSS 208, Snell, and JIS-T (Juste-Lorente et al. 2022). A review of these programs shows that the testing conditions and the assessment parameters used differ from one program to another. However, in most LMICs, national standards for helmets either do not exist or do not specifically include performance-based testing as part of the standard. Another relevant issue is how to assess whether the impact response of the helmets is maintained over time; for instance, under extreme weather conditions (such as those experienced in the tropics) or when they are repaired or reused after a crash, circumstances that occur frequently in LMICs. Compounding this complexity, countries may lack capacity to ensure that all certified helmets on the market comply with the corresponding regulatory standards. Driven by increased enforcement of helmet use and lack of adequate certification procedures, the market in LMICs is usually flooded with cheap and uncertified helmets. This has been demonstrated in research documenting a large prevalence (54%) of uncertified helmets from market and motorcycle rider surveys in 9 developing countries (Ackaah et al. 2013). This finding was true even in countries that had legislation prohibiting the sale of uncertified helmets, which are cheaper (33% of the cost) than certified helmets.

Our goal is to conduct an initial exploration on whether “certification” of the helmets has any influence on their laboratory impact response, while controlling for other physical parameters of the helmets.

Methods

Fifty-five helmets commonly sold in China, Colombia, India, Indonesia, Iran, Malaysia, Russia, Thailand, Uganda, and the United States were purchased in regular stores. The sample included certified and noncertified helmets, including full-face, open-face, and half-helmet styles.

Drop tests were conducted using a vertical drop tower with a dual set of linear bearings and a manual release system at the Center for Applied Biomechanics of the University of Virginia. The helmets impacted a flat steel anvil that was 5 in. in diameter, in compliance with the

USDOT standard FMVSS 218. An instrumented Hybrid III dummy head and neck were used in the drop tests.

Each helmet was dropped 6 times, twice at each of 3 locations: front, rear, and side. The locations and repetitions were chosen to mimic the USDOT and UNECE testing requirements and all impacts were located above the test line defined by the USDOT standard (Standard No. 218, Regulation 22). For each test, the helmet was raised to a drop height of 72 in. and released, to achieve an impact velocity close to 6.0 m/s. Helmets were weighted and the thickness of the liner was measured at approximately the 3 impact locations.

Collected data were filtered (CFC1000) and analyzed in MATLAB (MATLAB 2022). Four outcomes were extracted: peak resultant linear acceleration at the center of gravity of the Hybrid III head form (PLA), head injury criterion (HIC), peak resultant angular velocity (PAV), and brain injury criterion (BrIC). These 4 outcomes were compared using 4 linear regression models (1 per outcome) per each impact configuration. The independent variables in these regression models were the mass of the helmet, the thickness of the liner padding measured at the location of the impact, and whether the helmet was certified or not. Only the first impact per impact configuration was considered in these regressions.

Results

Descriptive analysis

Of the 55 helmets in the sample, 33 were certified and 22 were noncertified. Mean PLA was slightly higher in the

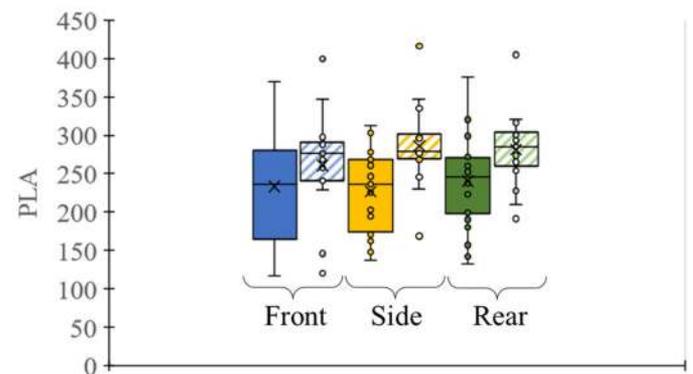


Figure 1. Comparison of peak linear acceleration (g) per impact direction between certified (solid) and noncertified (light color) helmets.

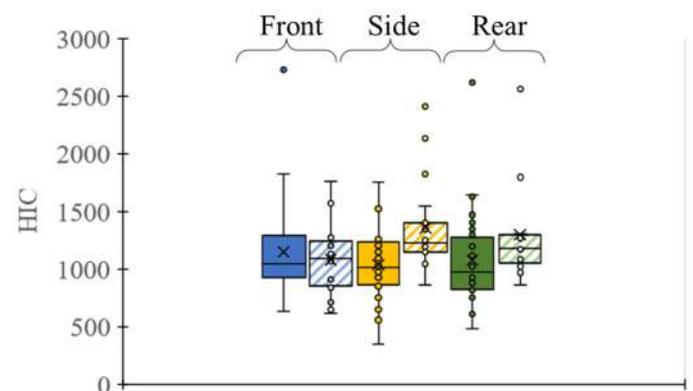


Figure 2. Comparison of HIC per impact direction between certified (solid) and noncertified (stripes) helmets.

noncertified group than in the certified group (front: 233.2 g vs. 260.5 g; side: 226.9 g vs. 286.2 g; rear: 240.4 g vs. 281.7 g) regardless of the impact location (see Figure 1). This was true also for the median of the distribution. The variability of PLA results in the certified group was greater than that in the noncertified group, as illustrated in the plots. The distribution of the HIC (Figure 2) value showed the same trend, in which the certified helmets resulted in lower average HIC values, and the differences were larger in the side and rear impact locations. In the case of the 2 rotational outcomes considered, PAV and BrIC, the differences between the 2 groups are more important, especially in the lateral impact location. In this case, the average value of the certified helmets was greater than the 75th percentile of the distribution of the PAV and BrIC of the noncertified group. The variability within the certified group was also greater (see Figure 3).

The average HIC value across helmets purchased in different countries was similar and ranged between 1,019 (Malaysia) and 1,456 (India). The HIC variability in the helmets purchased in Colombia, India, and Indonesia was higher than that for helmets purchased in other countries. Out of the 4 outliers in the helmets from China, the 2 largest HIC values corresponded to certified helmets. Helmets purchased in the United States performed better in PLA and HIC, and not only they resulted in the lowest average magnitudes, but the variability of the sample was also the smallest among all countries (PLA = 183.5 ± 42.5 g and HIC = 831 ± 183). It should be noted that all U.S. helmets were certified and that the FMVSS 218 establishes a peak acceleration limit of 400 g.

Linear regression models

In the impacts to the front of the helmet, none of the independent variables, including certification, were significantly associated with any of the outcomes. In side impacts, certified helmets had a significantly lower PLA and significant increases in PAV and BrIC. The only significant effect in rear impacts was that certification reduced the PAV in the tested helmets.

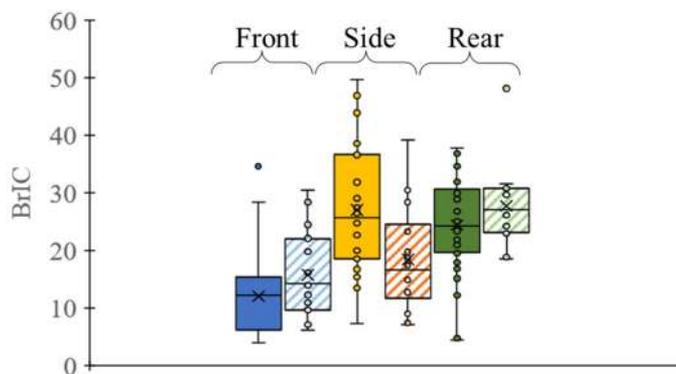


Figure 3. Comparison of BrIC per impact direction between certified (solid) and noncertified (stripes) helmets.

Discussion

This short communication presents the results observed from drop tests performed under conditions like those used in the USDOT standard FMVSS 218 of 55 helmets from 10 countries. Although we have focused only on the impact response of helmets, it should be noted that several certification programs include other tests such as penetration tests, visor light transmission, strap security, etc. To our knowledge, no other study has performed this comparison in such a large sample of helmets from different countries with different income levels.

The results show that certified helmets performed only slightly better than uncertified helmets in the outcomes that were related to the linear acceleration of the head form (PLA and HIC). This is not surprising because most certification programs are based on limiting these values. However, the regression models did not show statistical significance of the certification for the impacts to the front and to the rear parts of the helmets. The results observed for the outcomes related to the rotation of the head showed slightly smaller values for the certified group in front and rear impacts but significantly larger values for the impacts to the side of the helmet. Our findings challenge the hypothesis that certification always ensures safer helmets.

The 2021–2030 Decade of Action to halve road deaths calls for a specific (voluntary) target aimed to increase the proportion of motorcycle riders correctly using certified helmets to close to 100% by 2030. We acknowledge the limitation of our pilot study in that helmets were not randomly secured to produce a robust sample of all helmets sold worldwide. Yet, these results intrigue us because they challenge the commonly held belief that certification is a guarantee of safety.

Certification is a quality assurance process and when done right it should have a positive effect on ensuring performance at least for some specific impact conditions, although it increases the cost of products on the market. Producing a safer helmet also increases its production costs. With so many motorcycle riders to protect, ensuring a streamlined criterion that identifies whether helmets provide significant protection with respect to no helmet use is a query worthy of further research.

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Comparison of small female occupant model responses with experimental data in a reclined posture

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ABSTRACT

Objective: The objective of the current study was to compare the GHBMC female model responses with in-house sled test data for three small female post mortem human surrogates (PMHS) at 32 km/h and a seat-back recline angle of 45 degrees. The kinematics and the seatbelt forces were used to compare the female PMHS and model responses. The study aimed to identify updates that may be needed to the model.

Methods: In-house experimental sled test kinematic and seatbelt response data for the small females were obtained. The 5th female GHBMC was simulated with the same boundary conditions as in the experiments. In addition, using the PMHS computed tomography (CT) and test environment scans, the female model geometry was updated to a subject-specific model for one of the specimens, and the models were simulated to obtain 5th female and subject-specific model responses. The kinematic response and the seatbelt forces for the two models were compared with the average of the three experimental data.

Results: The head, T8 and L4 excursions, head and pelvis accelerations and seatbelt forces for the two female models were compared with the experimental data. The model responses were in agreement with the PMHS; however, the subject-specific model showed a closer agreement with the kinematic response. The subject-specific model did not submarine as in the experiments, whereas the 5th female model submarined. However, the subject-specific model showed 20% higher seatbelt forces than the PMHS.

Conclusion: This study showed that anthropometric differences may significantly alter occupant kinematics in reclined posture and need to be incorporated to investigate kinematics and injury mechanisms. The next step of the study involves incorporating age-specific material changes and investigating the subject-specific injury mechanisms. The results will be useful to develop countermeasures for autonomous vehicles.

KEYWORDS

Human body model; reclined posture; female response; subject-specific model; biomechanics

Introduction

The occupant posture for New Car Assessment Program (NCAP) and US Federal Vehicle Motor Safety Standards (FMVSS) are well defined with a seat back angle of approximately 25 deg. New and upcoming autonomous vehicles will allow the occupant to get involved in activities other than the driving. A questionnaire to investigate seating

preferences in a fully autonomous vehicle showed that the majority of the participants showed a desire for reclined seats to watch a movie, read, or rest (Jorlov et al. 2017). An experimental study investigated thoracolumbar and pelvis kinematics of males approximating 50th percentile anatomy in a reclined posture. The results showed increased spine compression and one occupant demonstrated submarining

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