Insurance Institute for Highway Safety
Highway Loss Data Institute

4121 Wilson Boulevard, 6th floor
Arlington, VA 22203
+1 703 247 1500

988 Dairy Road
Ruckersville, VA 22968
+1 434 985 4600

iihs.org

July 24, 2023

Ms. Anne Carlson
Acting Administrator
National Highway Safety Administration
1200 New Jersey Avenue, SE
Washington, DC 20590

Request for Comments: New Car Assessment Program, Docket No. NHTSA-2023-0020

Dear Ms. Carlson:

The Insurance Institute for Highway Safety (IIHS) welcomes the opportunity to comment on the proposal by the National Highway Traffic Safety Administration (NHTSA) to update the New Car Assessment Program (NCAP) with information about crashworthiness pedestrian protection of new vehicles.

IIHS supports NHTSA's intent to improve pedestrian protection in vehicle-to-pedestrian crashes but the proposal in its current form falls far short. Specifically, pedestrian crashworthiness should be mandated in all new vehicles. Including it in NCAP as a voluntary pass/fail measure will not compel automakers to make substantive changes for all passenger vehicles, particularly vehicles with tall front ends like large SUVs and pickups that are most likely to cause serious pedestrian injuries in crashes. NHTSA must think more systematically and use all assessment and regulatory tools available to it to protect pedestrians. The Safe System approach adopted in the 2022 U.S. Department of Transportation (DOT) National Roadway Safety Strategy demands more holistic thinking to protect all road users.

IIHS recommends that NHTSA expedite its efforts to regulate pedestrian crashworthiness to ensure all vehicles have a baseline level of pedestrian protection. As NHTSA (2023) stated in its own recent Notice of Proposed Rulemaking on automatic emergency braking (AEB) systems for light vehicles (Docket No. NHTSA-2023-0021), a primary reason for pursuing regulation over consumer-information ratings is to "target one of the most concerning and urgent traffic safety problems facing the U.S. today—the rapidly increasing numbers of pedestrian fatalities and injuries." NHTSA noted that NCAP is "intended to supplement rather than substitute for the FMVSS, which remain NHTSA's core way of ensuring that all motor vehicles are able to achieve an adequate level of safety performance." If the goal is to stem the expanding problem of pedestrian injuries and fatalities, it is wholly inconsistent to not couple pedestrian crash avoidance mandates with similar mandates for pedestrian crashworthiness improvements. NCAP ratings are a great tool for consumers looking for the best protection for their family, but it may be optimistic to expect consumers to seek out protection for those outside of the vehicle with equal enthusiasm. NHTSA used the same reasoning in their proposal to mandate pedestrian AEB when they stated, "It is not clear if past experiences with NCAP are necessarily indicative of how quickly PAEB systems would reach the levels of lead vehicle AEB, if pedestrian functionality that would meet NCAP performance levels was offered as a separate cost to consumers."

If included in NCAP instead of regulation, IIHS recommends the pedestrian crashworthiness ratings be comprehensive and highly visible, included in the overall 5-star safety rating, and not rely on voluntary participation. Consumer-information ratings programs are most effective when the results are highly visible and public, are easily obtainable by consumers, and provide comparative information about performance. There are several aspects of NHTSA's proposal that will limit its effectiveness in incentivizing necessary vehicle improvements. First, voluntary participation provides little incentive for manufacturers of the worst-performing vehicles and manufacturers for which making improvements presents the greatest challenge to participate in the ratings program. Thus, voluntary participation limits NHTSA's ability to publicize poor performance and encourage effective countermeasures. Second, excluding the ratings from NHTSA's overall 5-star safety rating means that vehicles can claim top ratings even with a failing pedestrian protection score, thereby eliminating the leverage the overall rating has to compel automakers to implement improvements. Similarly, if a vehicle is not expected to pass, there is no incentive for the automaker to improve pedestrian crashworthiness beyond the existing design. Third, a pass/fail scheme does not allow consumers to compare relative performance across vehicles.

IIHS recommends that NHTSA consider evaluations that account for the outsize role larger vehicles, such as SUVs and pickups, play in U.S. pedestrian fatalities. The proposed component test suite will assess vehicle component stiffness but does nothing to curb the growing hood heights of vehicles, especially found among vehicles with tall and boxy front ends, predominantly larger SUVs and pickups. Our research has found that SUVs are more likely to injure and kill pedestrians compared with smaller, shorter cars, and that these vehicles inflict a greater number of serious thorax injuries from contact with the grille, headlights, and hood leading edge (Monfort & Mueller, 2020). Vehicles with higher hood leading edges also are more likely to throw pedestrians to the ground, a more dangerous kinematic response compared with what occurs with a lower and sloped front end that causes the pedestrian to wrap around the vehicle and one not assessed by the proposed test suite.

A recent IIHS study examined detailed measurements of front-end shapes and determined higher hood leading edges (> 40 inches), or medium-height hood leading edges (30–40 inches) with boxy front-end shapes contribute to greater risk of fatality (Hu et al., 2023*;* see Appendix A for a summary of the preliminary results of this study); such vehicles are growing in popularity and contributing to the increases in pedestrian fatalities seen in recent years (Hu & Cicchino, 2018). NHTSA should examine ways to modify these pedestrian crashworthiness evaluations to reward vehicle front-end shapes associated with lower fatality rates, such as those with lower hood-leading-edge heights and sloping hoods. Relatedly, IIHS recommends that vehicles with tall bumper heights not be excluded from scoring eligibility; doing so removes any incentive for automakers to pursue countermeasures on these vehicles, which are often needed because injuries caused by tall bumper heights are the most dangerous to pedestrians.

In summary, IIHS applauds NHTSA's efforts to address the alarming increase in pedestrian fatalities and improve pedestrian crash outcomes. However, we urge NHTSA to take a stronger approach and regulate minimum performance requirements for all vehicles. If included in NCAP, we urge NHTSA to incorporate the ratings in a manner that best incentivizes improvements, especially for vehicles most likely to cause harm.

Our detailed answers to select questions posed by NHTSA are appended below and include both suggestions for augmenting the evaluation of pedestrian crashworthiness and ideas for future consideration.

Sincerely,

Becky Mueller
Senior Research Engineer

Answers to select questions posed in Docket No. NHTSA-2023-0020

Q4. An Agency study of Abbreviated Injury Scale (AIS) 3+ pedestrian injuries in the U.S. showed that the apportionment of points in NCAP for crashworthiness pedestrian protection should be 3/8th for head impact test results (37.5 percent), 3/8th for lower leg impact test results (37.5 percent), and 2/8th for upper leg impact test (25 percent). NHTSA seeks comment on whether injury severity or frequency would be the most appropriate basis for point allocation apportionment.

NHTSA should allocate a larger proportion of points for test results associated with serious and fatal pedestrian injuries to address the rapidly increasing numbers of pedestrian fatalities.

Studies of serious and fatally injured pedestrians in the United States, United Kingdom, Germany, and Japan have shown that the head is the most commonly injured body region and that serious head injuries are frequently from vehicle A-pillars and windshields, components evaluated by the European (Euro) NCAP headform test zones (Badera-Romero & Lenard, 2012; Mallory et al., 2012; Mueller et al., 2012; Ono et al., 2005; Richards et al., 2009). Studies of real-world crashes have shown that improved headform test performance is associated with reductions in serious injuries and fatalities (Liers, 2009; Mueller et al., 2013). While leg injuries occur frequently (Mallory et al., 2012; Mueller et al., 2012), even the most severe leg injuries pose a lower threat to life than many head injuries. In addition, real-world benefit estimations show mixed results on whether lower legform test performance relates to real-world injury reductions (Liers, 2009; Mueller & Nolan, 2017).

Using injury severity as the basis to apportion points is a start toward addressing the most serious injuries, but regulating minimum performance requirements is the most effective way to achieve this goal for all vehicles, including vehicles that might be excluded from the current proposal.

Q5. As concluded in the Agency's FlexPLI research report, NHTSA believes the FlexPLI legform is biofidelic and seeks comment from the public on whether biofidelity concerns with the FlexPLI still remain at this time.

IIHS does not recommend that NHTSA utilize the FlexPLI as its first choice. NHTSA instead should choose the aPLI, developed through the Society of Automotive Engineers of Japan and ISO/TC 22/SC 36/WG 5and WG 6 [1], this aPLI includes an upper body mass to address kinematic fidelity concerns with the older FlexPLI device (Konosu et al., 2016).

The aPLI is already in wide use by other testing organizations with defined performance limits, including Euro NCAP, China NCAP, and Korea NCAP, and it will be introduced by Japan NCAP next year (Euro NCAP, 2022). NHTSA's report (Suntay & Stammen, 2022) on testing with the aPLI also demonstrated favorable results in terms of usability, realistic impact kinematics, and additional sensor capabilities.

Questions 6, 7, and 14

Q6. NHTSA is seeking comment on what procedure it should use for marking the test zone on bumpers. In other words, should the procedure harmonize with the Euro NCAP 60-degree angle method, or should it follow the GTR 9 and UNECE R127 corner gauge method?

Q7. GM suggested that if a vehicle has an exposed bumper, the bumper test zone should use the 60-degree angle method instead of testing the full bumper width to eliminate testing at the

[1] The International Organization for Standardization's (ISO's) Technical Committee 22, Subcommittee 36, and Working Groups 5 and 6 (https://www.iso.org/committee/5383958.html).

extreme edge of what may be a curved bumper. NHTSA requests comment on this concern as well, as it is similar to the previous question for bumper test zones.

Q14. NHTSA tentatively plans to use the corner gauge and bumper beam width procedure for corner definition for this NCAP proposal and requests comment on this change.

In response to questions 6, 7, and 14, IIHS urges NHTSA to use caution when applying methods that could artificially reduce the applicable impact zones. Pedestrians impact various locations across the vehicle width (Grover et al., 2015; Mueller et al., 2012); therefore, to the extent practicable, NHTSA should strive to ensure pedestrian crashworthiness exists on the entire vehicle width.

Q8. Given the pedestrian death and injury crisis on U.S. roadways, NHTSA is seeking comment on test speeds. Should test speeds for either of the head or leg tests be increased in an attempt to provide better protection to pedestrians in vehicle-to-pedestrian crashes? Should the area of assessment be increased beyond the WAD 2,100 mm currently proposed to account for pedestrian heads overshooting the hood and impacting the windshield or the roof of the vehicle?

NHTSA should focus its initial efforts on adopting a regulation that establishes a minimum level of pedestrian protection for all vehicles using well-established baseline test scenarios and impactor speeds. NCAP can be used to supplement the regulation with evaluations of increased speed or alternative test configurations to provide consumers with comparative vehicle performance beyond minimum requirements. Extensive research has shown that speed is a significant factor in pedestrian injury outcomes (Hussain et al., 2019; Jermakian & Zuby, 2011; Monfort & Mueller, 2020; Rosén et al., 2011; Rosén & Sander, 2009), but additional research is needed to determine impactor biofidelity, the feasibility of countermeasures, and potential design tradeoffs associated with component tests conducted at higher severities.

IIHS recommends that NHTSA expand the proposed head test zone to a minimum wrap-around distance (WAD) of 2,500 mm, as Euro NCAP tests per their current protocols (Euro NCAP, 2022). While vehicle windshields and A-pillars are common head injury sources, many of the real-world head impacts are from parts of the windshield and A-pillars beyond the 2,100-mm WAD zone (Mueller et al., 2012; Wang et al., 2020). A 2023 IIHS survey of 93 model year 2022 vehicles suggests that the test zone should extend even higher to fully cover the windshield and A-pillars of modern U.S. vehicles, as the average top-of-windshield WAD ranged between 2,800 and 3,100 mm, depending on vehicle type (see Appendix B for more information).

IIHS remains concerned that test protocols may not assess some of the most important aspects of vehicles contributing to pedestrian injuries. SUVs and pickups are increasingly popular vehicles in the U.S. and are responsible for a disproportionate number of pedestrian injuries and fatalities (Hu & Cicchino, 2018; Lefler & Gabler, 2004; Longhitano et al., 2005; Monfort & Mueller, 2020). A recent IIHS study of police-reported pedestrian crashes showed that vehicles with either (a) higher (> 40 inches) hood leading edges; or (b) medium-height (30–40 inches) hood leading edges and vertical front ends contribute to greater incidence of fatality (Hu et al., 2023; see Appendix A for a summary). Higher hood leading edges have been associated with increased risk of serious or fatal thorax injuries (Longhitano et al., 2005; Monfort & Mueller, 2020; Zhang & Hu, 2008). Neither vehicle hood height nor front-end slope are explicitly evaluated in the proposed testing suite, nor are there tests involving an impactor that mimics a pedestrian thorax. At the same time, vehicles have continued to get larger and taller based on styling trends and consumer demand, but currently no regulations or evaluations exist to constrain these designs. NHTSA should consider test conditions or evaluation criteria that promote vehicle front-end shapes that are most favorable to pedestrian injury outcomes, in addition to tests that focus solely on stiffness assessments of individual vehicle components and limited body regions.

Q9. NHTSA requests comment on the seven Euro NCAP documents proposed in section IV. F. (Euro NCAP Pedestrian Testing Protocol, Version 8.5; Euro NCAP Assessment Protocol—Vulnerable Road User Protection Part 1—Pedestrian Impact Assessment, Version 10.0.3; Euro NCAP Pedestrian Headform Point Selection, V2.1; Euro NCAP Film and Photo Protocol Chapter 8—Pedestrian Subsystem Tests, V1.3; Euro NCAP Technical Bulletin TB 008 Windscreen Replacement for Pedestrian Testing, Version 1.0; Euro NCAP Technical Bulletin TB 019 Headform to Bonnet Leading Edge Tests, Version 1.0; and Euro NCAP Technical Bulletin TB 024 Pedestrian Human Model Certification, V2.0)—do any elements of these documents need modification for the U.S. NCAP?

Unless NHTSA has identified specific issues with the latest generation of Euro NCAP protocols (which are a newer generation than the NHTSA-proposed protocols), NHTSA should use the latest version of the Euro NCAP pedestrian test protocols and devices: *Euro NCAP Pedestrian Testing Protocol (Version 9.0.3)* and *Euro NCAP Assessment Protocol—Vulnerable Road User Protection Part 1—Pedestrian Impact Assessment (Version 11.3)*. These protocols, which have already been adopted by various NCAPs, specify the use of a new lower leg impactor, aPLI, and extend the head test zone to WAD 2,500 mm to assess a larger proportion of the vehicle hood, windshield, and A-pillars. Without referencing the shortcomings of the latest protocols, it seems illogical to choose an outdated set of protocols to assess future vehicles.

Questions 11 and 20

Q11. NHTSA seeks comment on what level of detail should be required for self-reported data. Should manufacturers be allowed to submit predicted head and leg response data, or only actual physical test results? Should reporting consist of just the results for each test location, or should full data traces or a comprehensive test report including photographs and videos be required?

Q 20. NHTSA seeks comment on the proposal to conduct verification testing as part of the crashworthiness pedestrian protection program by adjusting the head score using a conversion factor determined from laboratory tests and replacing manufacturer-supplied FlexPLI and upper leg scores with NHTSA scores from laboratory tests.

In theory, IIHS supports efforts to accept predicted results, but the current proposal does not contain sufficient NHTSA surveillance. Simulation has the potential to add significant value to automotive and roadway safety by expanding the number and type of assessed scenarios. A key requirement for simulation, however, is that simulation results are verified to align with physical test results. For example, the Euro NCAP pedestrian protocols only accept self-reported predicted scores for the entire hood after completing physical verification of select points, which we believe is a robust method for incorporating simulation. NHTSA's proposal of only physically testing select vehicles is not sufficient to provide the necessary evidence to validate the predicted results of untested vehicles. IIHS believes that accepting simulation results without sufficient oversight may set the wrong precedent for building confidence in virtual testing results.

Our audit testing process and experience with manufacturer self-reported data has been highly successful. It allows us to provide more ratings on our website than our capacity to conduct in-house crash tests while also ensuring the integrity of test results received. All submitted data, including data traces, measurements, and photography are scrutinized by engineers in a rigorous quality control process. We support NHTSA's proposal to accept manufacturer self-reported test data but recommend that NHTSA request comprehensive data including data traces and photography, not just a summary of results for each test location. For audit testing, IIHS recommends that sufficient points be tested per vehicle to ensure that different front-end structures and aspects of the entire test zone are evaluated in the audit process.

The approach proposed includes minimal efforts by NHTSA for vetting manufacturer-submitted data and is insufficient to adequately assess the validity of the data. Voluntary submission of self-reported data provides little incentive for manufacturers of the worst-performing vehicles and for manufacturers for which making improvements presents the greatest challenge to participate in the ratings program. At a minimum, NHTSA should undertake a more stringent verification process to cross-check self-reported data. Fundamentally, these obstacles highlight the need for this testing to be part of regulation to ensure that all vehicles provide a minimal level of performance.

Q 12. NHTSA requests comment on whether vehicles with an LBRL greater than 500 mm should be eligible to receive crashworthiness pedestrian protection credit because they will automatically receive a zero score for the FlexPLI bumper tests.

We do not support excluding a vehicle from eligibility based on lower bumper height, especially when vehicles that typically fall into this category are popular and disproportionately deadly to pedestrians (Hu & Cicchino, 2018). This is a missed opportunity for those vehicles to be recognized for other potential safety advances. Vehicles with lower bumper reference lines above 500 mm can still be designed with countermeasures that lower risks of injury to pedestrians' hips, thighs, and heads through the upper legform and headform testing and should have an opportunity to receive credit for such countermeasures. This can further be incentivized by creating a comparative scale for performance, instead of a pass/fail checkmark, or by including pedestrian performance as part of the consumer-facing 5-star safety ratings. Ultimately, the most effective way to ensure all vehicles, regardless of bumper height, are designed with pedestrian crashworthiness is to implement a minimum set of performance criteria through regulation.

Q 18. NHTSA seeks comment on whether [a checkmark on NHTSA.gov] is an appropriate way to identify vehicles that meet the Agency's minimum criteria for crashworthiness pedestrian protection, or if some other notation or identifying means is more appropriate.

A pass/fail designation is best suited for regulatory evaluations. Consumer-information ratings programs are most effective when the results are public and highly visible and provide comparative information about performance. The pass/fail checkmark does not allow consumers to compare relative performance across vehicles. Additionally, if a vehicle is not expected to pass, there is no incentive for the automaker to improve pedestrian crashworthiness beyond the existing design. Finally, voluntary participation will likely lead to the manufacturers of the worst-performing vehicles foregoing participation in the ratings. At a minimum, pedestrian crashworthiness performance should be included in the overall 5-star safety rating to provide greater visibility of results to consumers and give manufacturers greater incentive to submit test data.

References

Badera-Romero, A., & Lenard, J. (2012). Source of head injury for pedestrians and pedal cyclists: Striking vehicle or road? *Accident Analysis & Prevention*, *50*,1140-1150. http://doi.org/10.1016/j.aap.2012.09.024

European New Car Assessment Programme. (2022). *Vulnerable road user testing protocol (Version 9.0.3)*.

Grover, C., Avery, M., & Knight, I. (2015). The development of a consumer test procedure for pedestrian sensitive AEB. Paper No. 15-0159. Proceedings of the 24th International Technical Conference on the Enhanced Safety of Vehicles (ESV) .

Hu, W., & Cicchino, J. B. (2018). An examination of the increases in pedestrian motor-vehicle crash fatalities during 2009–2016. *Journal of Safety Research*, *67*, 37—44. https://doi.org/10.1016/j.jsr.2018.09.009

Hu, W., Monfort, S. S., & Cicchino, J. B. (2023). *Relationship between passenger vehicle front-end profiles and pedestrian injury severity in motor vehicle crashes* [Manuscript in preparation]. Insurance Institute for Highway Safety.

Hussain, Q., Feng, H., Grzebieta, R., Brijs, T., & Olivier, J. (2019). The relationship between impact speed and the probability of pedestrian fatality during a vehicle-pedestrian crash: A systematic review and meta-analysis. *Accident Analysis & Prevention*, *129*, 241-–249. https://doi.org/10.1016/j.aap.2019.05.033

Insurance Institute for Highway Safety. (2023). Measurement of centerline wrap distances to vehicle landmarks for 93 model year 2022 vehicles by vehicle type [unpublished data].

Jermakian, J., & Zuby, D. (2011). Primary pedestrian crash scenarios: Factors relevant to the design of pedestrian detection systems. Insurance Institute for Highway Safety.

Konosu, A., Isshiki, T., & Takahashi, Y. (2016). Development and evaluation of the advanced pedestrian legform impactor prototype which can be applicable to all types of vehicles regardless of bumper height - Part 2: Actual test tool. *Proceedings of the 2016 IRCOBI Conference*, (pp. 786–799).

Lefler, D. E., & Gabler, H. C. (2004). The fatality and injury risk of light truck impacts with pedestrians in the United States. *Accident Analysis & Prevention*, *36*(2), 295–304. https://doi.org/10.1016/S0001-4575(03)00007-1

Liers, H. (2009). Benefit estimation of the Euro NCAP pedestrian rating concerning real-world pedestrian safety. Paper Number 09-0387. *Proceedings of the 21st International Technical Conference on the Enhanced Safety of Vehicles (ESV)*.

Longhitano, D., Henary, B., Bhalla, K., Ivarsson, J., & Crandall, J. (2005). Influence of vehicle body type on pedestrian injury distribution. *SAE Transactions*, 2283–2288. https://doi.org/10.4271/2005-01-1876

Mallory, A., Fredriksson, R., & Donnelly, B. (2012). Pedestrian injuries by source: Serious and disabling injuries in US and European cases. *Annals of Advances in Automotive Medicine: Association for the Advancement of Automotive Medicine Annual Scientific Conference*, 56, 13–24.

Monfort, S. S., & Mueller, B. C. (2020). Pedestrian injuries from cars and SUVs: Updated crash outcomes from the Vulnerable Road User Injury Prevention Alliance (VIPA). *Traffic Injury Prevention*, *21*(sup1), S165–S167. https://doi.org/10.1080/15389588.2020.1829917

Mueller, B., Farmer, C., Jermakian, J., & Zuby, D. (2013). Relationship between pedestrian headform tests and injury and fatality rates in vehicle-to-pedestrian crashes in the United States. *Stapp Car Crash Journal*, *57*, 185–199. https://doi.org/10.4271/2013-22-0007

Mueller, B., & Nolan, J. (2017). Pedestrian Flex-PLI legform test performance for seven early 2000's small cars. *Stapp Car Crash Journal*, *61*, 25–27.

Mueller, B. C., Nolan, J. M., Zuby, D. S., & Rizzo, A. G. (2012). Pedestrian injury patterns in the United States and relevance to GTR. *Proceedings of the 2012 IRCOBI conference* (pp. 690–702).

National Highway Traffic Safety Administration. (2023). 49 CFR Parts 571 and 596: Notice of proposed rulemaking. Federal Motor Vehicle Safety Standards: Automatic emergency braking systems for light vehicles. Docket No. NHTSA-2023-0021.

Ono, Y., Komiyama, Y., & Yamazaki, K. (2005). Introduction of pedestrian head protection performance test in J-NCAP. Paper No. 05-0307. *Proceedings of the 19th International Technical Conference on the Enhanced Safety of Vehicles (ESV)*.

Richards, D., Cookson, R., Cuerden, R., & Davies, G. (2009). The causes of pedestrians' head injuries following collisions with cars registers in 2000 or later. Paper No. 09-0459. *Proceedings of the 21st International Technical Conference on the Enhanced Safety of Vehicles (ESV)*,

Rosén, E., & Sander, U. (2009). Pedestrian fatality risk as a function of car impact speed. *Accident Analysis & Prevention*, *41*(3), 536–542. https://doi.org/10.1016/j.aap.2009.02.002

Rosén, E., Stigson, H., & Sander, U. (2011). Literature review of pedestrian fatality risk as a function of car impact speed. *Accident Analysis & Prevention*, *43*(1), 25–33. https://doi.org/10.1016/j.aap.2010.04.003

Suntay, B., & Stammen, J. (2022). *Comparison of the aPLI, FlexPLI with upper body mass, and FlexPLI pedestrian legforms in matched-pair vehicle tests* (Report No. DOT HS 813 086). U.S. Department of Transportation, National Highway Traffic Safety Administration.

Wang, S., Brown, E., Cunningham, K., Horbal, S. R., Rammelkamp, A., Kaufman, R., Trager, E. H., Kohoyda-Inglis, C., Holcombe, S., Schneider, A., Roth, F., Joyner, J., Mueller, B., Ables, N., & Keon, T. (2020). Head injuries from the Vulnerable Road User Injury Prevention Alliance (VIPA): Effect of vehicle type on head contact location. *Proceedings of the 2020 IRCOBI Conference* (pp. 307–315).

Zhang, G., & Hu, J. (2008). A field data analysis of risk factors affecting the injury risks in vehicle-to pedestrian crashes. *Annals of Advances in Automotive Medicine: Association for the Advancement of Automotive Medicine Annual Scientific Conference*, *52*, 199–214.

Appendix A

Summary of the 2023 IIHS study *Relationship between passenger vehicle front-end profiles and pedestrian injury severity in motor vehicle crashes* by Wen Hu, Samuel S. Monfort, and Jessica B. Cicchino

Logistic regression analysis evaluated the effects of passenger vehicle front-end profile parameters on the odds that a pedestrian was fatally injured in a single-vehicle crash, while controlling for the age and gender of drivers and pedestrians, environmental factors such as light and weather conditions, speed limits, and vehicle precrash movements. Crashes involving a single passenger vehicle and a single pedestrian ages 16 years or older were extracted from state crash data in seven states: Connecticut, Florida, Maryland, Michigan, New Jersey, Ohio, and Pennsylvania. Crash years included were from 2017 to 2020 or 2021, depending on the latest year for which crash data was available at the time of analysis. Vehicle front-end profile parameters were measured by using vehicle sideview photos in ImageJ, which is a free image-analysis tool.

The modeling results are presented in Table A1. Tall and boxy, tall and sloped, and medium height and boxy front ends were associated with significant increases of 43.8%, 45.6%, and 25.8%, respectively, in the odds that a pedestrian was fatally injured when compared with low and sloped front ends. There was a significant 24.8% increase in the odds if an engine hood angle was less than or equal to 15 degrees, compared with a hood angle larger than 15 degrees. An engine hood longer than 40 inches and a windshield angle larger than 30 degrees were associated with 6% and 10.7% increases in the odds, respectively, but the increases were not significant.

Table A1. Logistic regression modeling results of a single-vehicle single-pedestrian crash involving fatal pedestrian injuries

Parameter	Estimate	Change in odds that a pedestrian was killed in a crash	*p* value
Intercept	−4.0028		<.0001
Front-end shape indicator [a]			
Tall and boxy vs. low and sloped	0.3632	43.8%	0.0024
Tall and sloped vs. low and sloped	0.3754	45.6%	0.0354
Medium height and boxy vs. low and sloped	0.2298	25.8%	0.0173
Medium height and sloped vs. low and sloped	−0.0269	−2.7%	0.733
Low and boxy vs. low and sloped	0.0314	3.2%	0.7791
Hood length indicator			
> 40 inches vs. <= 40 inches	0.0585	6.0%	0.3425
Hood angle indicator			
<= 15 degrees vs. > 15 degrees	0.2217	24.8%	0.0012
Windshield angle indicator			
> 30 degrees vs. <= 30 degrees	0.1014	10.7%	0.1249
Vehicle precrash movement indicator			
Turning vs. going straight	−2.2937	−89.9%	<.0001

Parameter	Estimate	Change in odds that a pedestrian was killed in a crash	*p* value
Speed limit indicator			
30–35 mph vs. <= 25 mph	1.0453	184.4%	<.0001
40–50 mph vs. <= 25 mph	1.9661	614.3%	<.0001
>= 55 mph vs. <= 25mph	2.715	1410.5%	<.0001
Weather condition indicator			
Rain/snow/fog/wind/other vs. no adverse condition	−0.3152	−27.0%	0.0003
Light condition indicator			
Dark vs. daylight	1.2588	252.1%	<.0001
Dawn/dusk vs. daylight	0.8324	129.9%	<.0001
Driver gender indicator			
Female vs. male	−0.2144	−19.3%	0.0004
Pedestrian gender indicator			
Female vs. male	0.0638	6.6%	0.3008
Driver age indicator			
Driver 16–19 vs. 20–29	−0.0742	−7.2%	0.5754
Driver 30–49 vs. 20–29	−0.0789	−7.6%	0.3001
Driver 50–69 vs. 20–29	−0.1971	−17.9%	0.0137
Driver 70+ vs. 20–29	−0.3887	−32.2%	0.0007
Pedestrian age indicator			
Pedestrian 16–19 vs. 20–69	−1.1312	−67.7%	<.0001
Pedestrian 70+ vs. 2069	1.4289	317.4%	<.0001

[a] The front-end shape indicator was created by using the hood-leading-edge height and bumper lead angle to capture the combined effects. The bumper lead angle defined the boxy (> 65 degrees) versus sloped (<= 65 degrees) shape. The hood-leading-edge height defined the front-end height categories: tall (> 40 inches), medium height (> 30 inches and <= 40 inches), and low (<= 30 inches).

Appendix B

IIHS (2023) measured 93 model year 2022 vehicles, including cars, SUVS, and pickups, along the vehicle longitudinal centerline using a wrap distance method similar to that in the Euro NCAP pedestrian protocols to determine wrap distances of the hood leading edge, end of the hood, and top of the windshield.

This data, shown in Table B1, provides insight into the wrap distances required for testing to ensure that all aspects of the vehicle hood and windshield would be evaluated.

Table B1. Centerline wrap distances (mm) to vehicle landmarks for 93 model year 2022 vehicles by vehicle type.

Vehicle type	Hood leading edge (mm)	Hood end (mm)	Top of windshield (mm)
Car (n = 37)	740	1,850	2,790
SUV (n = 45)	900	1,980	2,930
Pickup (n = 11)	1,130	2,270	3,070