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Report to Congressional Committees

March 2023

VEHICLE SAFETY

DOT Should Take Additional Actions to Improve the Information Obtained from Crash Test Dummies

Accessible Version

GAO-23-105595

GAO Highlights

Highlights of GAO-23-105595, a report to congressional committees

March 2023

VEHICLE SAFETY

DOT Should Take Additional Actions to Improve the Information Obtained from Crash Test Dummies

Why GAO Did This Study

According to NHTSA, about 43,000 people died in vehicle crashes in 2021. Dummies provide information that helps improve the safety of vehicles through federal safety standards and safety ratings. However, the dummies used in NHTSA's crash tests may not adequately represent all demographic groups, including females and older individuals.

The Infrastructure Investment and Jobs Act included a provision for GAO to review the dummies used in NHTSA's vehicle safety crash tests. This report examines: (1) differences in risk of injury or death in crashes among certain demographic groups; (2) the extent to which the information dummies provide in crash tests helps mitigate those risks; and (3) steps NHTSA has taken to address any limitations in the information provided by dummies.

GAO reviewed relevant statutes, regulations, studies, and publications; interviewed NHTSA officials and a range of industry stakeholders, including researchers, auto manufacturers, and safety organizations; and evaluated NHTSA's risk management efforts.

What GAO Recommends

GAO recommends that NHTSA develop a plan to address limitations in the information provided by dummies. The plan should detail how efforts will respond to risks and set milestones.

NHTSA agreed with our recommendation.

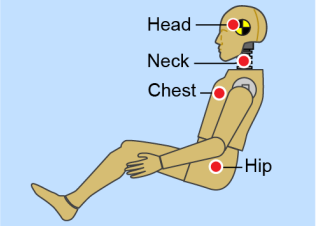
View GAO-23-105595. For more information, contact Elizabeth Repko at (202) 512-2834 or repkoe@gao.gov.

What GAO Found

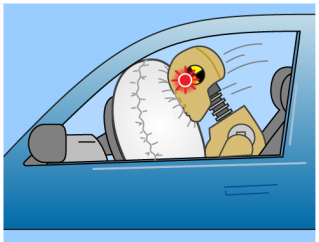
According to the National Highway Traffic Safety Administration (NHTSA), vehicles have become safer for occupants over time, in part by providing better protection in crashes. However, certain demographic groups continue to face greater risks of injury or death in crashes. Specifically, research indicates that in crashes with similar conditions, females are at greater risk of death and of certain injury types, such as to the lower legs, than males. In addition, vehicle occupants who are older are at greater risk than those who are younger, and occupants with a higher body mass index face some greater risks than those with a lower index.

Crash tests using crash test dummies provide information to improve vehicle safety, determine compliance with NHTSA's vehicle safety standards, and inform consumer safety ratings. However, some characteristics of dummies currently used for NHTSA's crash tests may limit the extent to which the information the dummies provide helps mitigate greater risks faced by certain demographic groups. For example, currently used dummies represent a limited range of body sizes, do not reflect some physiological differences between males and females, and do not have sensors to collect data in the lower legs. Limited ways in which dummies are used in crash tests—such as where the dummy sits and the speed of the crash—also may reduce the effectiveness of the information dummies provide in mitigating risks to certain demographic groups.

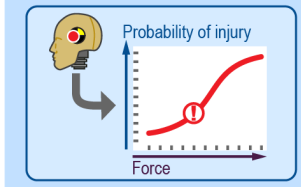
How Dummies Provide Information in Crash Tests to Estimate Crash Risks



Dummies contain instrumentation in various parts of the body.



During a crash test, instrumentation measure forces.



Measurements help estimate the potential for different injury types to a human vehicle occupant, including injuries to head, chest, and hips.

Source: GAO presentation of information from the National Highway Traffic Safety Administration. | GAO-23-105595

NHTSA has taken steps to address limitations in the information dummies provide in crash tests, but gaps remain. NHTSA has supported research into risks faced by demographic groups and has worked to develop technologically advanced dummies, among other efforts. However, these efforts have not fully responded to risks or consistently met milestones. For instance, NHTSA identified greater risks faced by females and older individuals at least two decades ago but has not completed actions to address those risks. NHTSA officials cited several factors for these gaps, including research and other challenges. While these factors contribute, NHTSA does not have a comprehensive plan to address existing risks and limitations in the information dummies provide. Without such a plan, NHTSA may miss opportunities to reduce inequities in crash outcomes among certain demographic groups.

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Abbreviations

Euro NCAP	European New Car Assessment Programme
FMVSS	Federal Motor Vehicle Safety Standards

NCAP	New Car Assessment Program
NHTSA	National Highway Traffic Safety Administration

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March 8, 2023

The Honorable Maria Cantwell
Chair
The Honorable Ted Cruz
Ranking Member
Committee on Commerce, Science, and Transportation
United States Senate

The Honorable Cathy McMorris Rodgers
Chair
The Honorable Frank Pallone, Jr.
Ranking Member
Committee on Energy and Commerce
House of Representatives

The National Highway Traffic Safety Administration (NHTSA) estimates that 43,000 people in the U.S. died in motor vehicle crashes in 2021—an increase of 10.5 percent from 2020, and the largest number since 2005. In addition, according to NHTSA, about 2.3 million people in the U.S. were injured in vehicle crashes in 2020. NHTSA oversees the safety of motor vehicles in part by setting the Federal Motor Vehicle Safety Standards (FMVSS) that motor vehicles and motor vehicle equipment must meet before they may be sold in the U.S., and by providing consumers with new vehicle safety ratings through the New Car Assessment Program (NCAP).[1]

A vehicle's compliance with the FMVSS and NHTSA's ratings are informed by data collected in crash tests using crash test dummies. These tests, which are intended to replicate real-world crashes, help determine the safety of individual vehicles and spur overall improvements in vehicle safety. However, given that vehicle occupants fall into a wide range of demographic groups, the extent to which the dummies currently used in tests provide information to help improve vehicle safety for all vehicle passengers, including those in various demographic groups, is unclear.

[1]NHTSA's general authority over motor vehicle safety is primarily codified at 49 U.S.C. Chapter 301. The FMVSS are the minimum safety standards.

The Infrastructure Investment and Jobs Act included a provision for us to conduct a review of the dummies used for NHTSA's vehicle safety crash tests.[2] This report addresses: (1) differences in risk of injury or death in vehicle crashes among various demographic groups, (2) the extent to which the information provided by dummies in crash tests helps to reduce the differences in risk among certain demographic groups, and (3) steps NHTSA has taken to address any limitations in the information provided by dummies in crash tests.

To examine the differences in risk of injury or death in vehicle crashes among various demographic groups, we reviewed relevant NHTSA studies, including studies published in 2013 and 2022 on the risks in vehicle crashes to certain demographic groups. We also conducted a literature search to identify relevant literature published from 2017 to 2022—including peer-reviewed studies, conference papers, and government reports. Based on this literature search we reviewed 28 relevant publications.[3]

To assess the extent to which the information provided by dummies in crash tests helps to reduce the differences in risk among certain demographic groups, we reviewed applicable statutes and regulations and information from NHTSA on the dummies and crash tests used to determine compliance with the FMVSS and inform NCAP vehicle safety ratings. We also obtained 2015 to 2018 data on adult weights and heights from the Centers for Disease Control and Prevention. We used those data to determine how the sizes of dummies compare to weights and heights of adult males and females.[4] We reviewed the methodology used to collect the data and determined the data were sufficiently reliable for

[2]Pub. L. No. 117-58, § 24221(a), 135 Stat. 429, 833-834 (2021). In response to this provision, we also provided a briefing on preliminary results to appropriate congressional staff in November 2022.

[3]A librarian conducted keyword searches in multiple databases including ProQuest, Scopus, EBSCO, and Dialog and identified 159 potentially relevant publications out of several hundred results. Two analysts then reviewed the titles and abstracts of those publications and selected 28 relevant publications that we then obtained and reviewed fully for relevant findings. We performed these database searches and identified articles from January 2022 to March 2022. We updated our search to focus on risks to children in November 2022. Of the 159 potentially relevant publications, 101 were from our initial search and 58 were from our subsequent search focused on risks to children. Of the selected 28 publications, 19 were from our initial search and nine were from our subsequent search focused on risks to children.

[4]U.S. Department of Health and Human Services Centers for Disease Control and Prevention National Center for Health Statistics, *Anthropometric Reference Data for Children and Adults: United States 2015-2018* Series 3, Number 46 (Hyattsville, MD: Jan. 2021).

reporting on the percentile data of American adults. In addition, we reviewed information from the European New Car Assessment Programme (Euro NCAP) on its use of dummies in crash tests.

To assess steps NHTSA has taken to address any limitations in the information provided by dummies in crash tests, we reviewed: (1) applicable statutes and regulations; (2) documents published in the Federal Register, such as requests for comment, related to dummies; (3) NHTSA documentation on past or proposed efforts that might address limitations in the information provided by dummies in crash tests; and (4) selected dummy-related regulatory actions proposed by NHTSA in the Unified Agenda of Regulatory and Deregulatory Actions. We also interviewed NHTSA officials about actions the agency has taken to address limitations in the information provided by dummies in crash tests. We then evaluated NHTSA's actions against its goals and objectives as described in DOT's strategic plans and good practices for risk management identified in prior GAO work.[5]

To inform all three objectives, we also interviewed NHTSA officials and industry stakeholders. We interviewed 26 industry stakeholder individuals or entities, including representatives from two automotive industry associations, six safety organizations, six vehicle manufacturers, a dummy manufacturer, and a developer and distributor of computer-based vehicle crash modeling, as well as researchers from eight centers or institutes, and two retired vehicle safety engineers.[6] We interviewed these stakeholders to represent a range of experiences with dummies and views on how dummies are used in crash tests. See appendix I for a list of all stakeholders interviewed.

[5]GAO, *Enterprise Risk Management: Selected Agencies Experiences Illustrate Good Practices in Risk Management*, GAO-17-63 (Washington, D.C.: Dec. 1, 2016).

[6]We interviewed: researchers from eight centers or institutes, based on publications we reviewed and recommendations from other stakeholders we interviewed; representatives from two automotive industry associations, based on their knowledge and position in the industry; representatives of six safety organizations, based on their knowledge and position in the industry and internet searches; two retired vehicle safety engineers, based on recommendations from other stakeholders we interviewed; representatives of six vehicle manufacturers, selected because their vehicle sales in the U.S. represent a majority of the market share, as well as to include both domestic and foreign companies; representatives of a dummy manufacturer, because it is the leading dummy manufacturer; and representatives of a developer and distributor of computer-based vehicle crash modeling, based on recommendations from other stakeholders we interviewed.

We identified key themes from these interviews using a content analysis.[7] We reported results from our content analysis by counting the number of responses assigned to each theme. We characterized the views of stakeholders from our 26 interviews in the following manner: "several" stakeholders means responses were counted in 3 to 5 of the interviews; "some" stakeholders means in 6 to 10 of the interviews; "many" stakeholders means in 11 to 15 of the interviews; and "most" stakeholders means 16 or more of the interviews. The other stakeholders not included in those counts did not necessarily disagree with a statement and may have instead not commented on the issue. The information from these interviews is not generalizable.

We conducted this performance audit from December 2021 to March 2023 in accordance with generally accepted government auditing standards. Those standards require that we plan and perform the audit to obtain sufficient, appropriate evidence to provide a reasonable basis for our findings and conclusions based on our audit objectives. We believe that the evidence obtained provides a reasonable basis for our findings and conclusions based on our audit objectives.

Background

NHTSA's Federal Motor Vehicle Safety Standards and Consumer Ratings

NHTSA's mission is to save lives, prevent injuries, and reduce economic costs due to road traffic crashes. To do so, NHTSA undertakes a number of efforts including supporting public education campaigns, conducting and supporting research, and regulating vehicle and vehicle equipment safety. As part of these efforts, NHTSA administers the FMVSS and runs NCAP.

- **FMVSS.** The FMVSS are regulatory standards that specify the federal minimum performance requirements with which new motor vehicles

[7]First, we identified potential categories for themes based on our three research objectives. Then one analyst coded the interview responses and inductively refined codes as needed. Finally, another analyst verified these codes, and we resolved any coding discrepancies through discussion.

and motor vehicle equipment must comply to be sold in the U.S.[8] Some standards specify crash avoidance requirements, such as those related to brakes, and others specify crashworthiness requirements, such as seat belts. The standards for occupant crash protection are intended to reduce the number of deaths and severity of injuries during crashes by specifying requirements for vehicle crashworthiness and for restraint systems, such as seat belts, through crash and other types of tests.[9]

- **NCAP.** NCAP, established in 1978, is a consumer information program that annually provides comparative information on the safety performance of new vehicles to assist consumers with vehicle purchasing decisions and encourage vehicle manufacturers to adopt safety improvements. As part of NCAP, new vehicles are tested to determine how well they protect occupants during crashes and are rated using a 5-star safety system (with 5 stars being the highest rating). Vehicle manufacturers must include any NCAP safety ratings for a vehicle on the vehicle's consumer information label.[10] The model year 2022 vehicles tested and rated through NCAP represent 86 percent of the new vehicle fleet.

Use and History of Crash Test Dummies

Both FMVSS compliance and NCAP ratings are informed by a range of front- and side-impact crash tests that use dummies (see fig. 1). According to NHTSA, information from crash tests help to determine the safety of vehicles, ensure FMVSS compliance, and spur overall improvements in vehicle safety by encouraging vehicle manufacturers to design vehicles that obtain high NCAP ratings. These crash tests require significant resources to conduct, including the vehicle being crashed, the dummy, and time to set up the crash test.

[8]The FMVSS are located in 49 C.F.R. Part 571. Manufacturers must certify that their motor vehicles or motor vehicle equipment comply with applicable FMVSS before their motor vehicles or motor vehicle equipment can be sold in the U.S. *See* 49 U.S.C. §§ 30112, 30115.

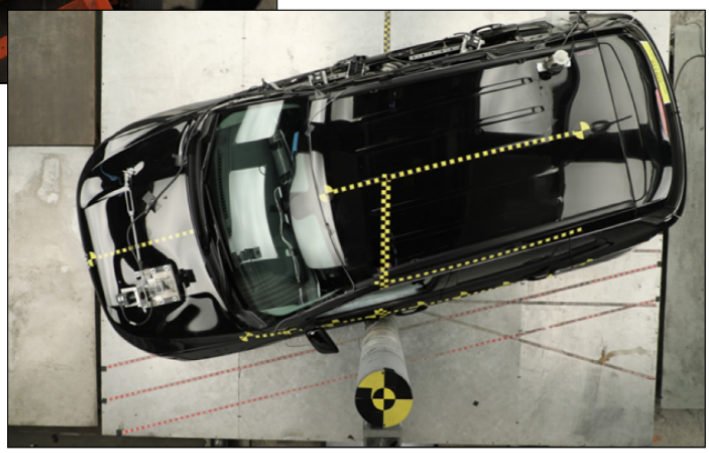
[9]*See* FMVSS No. 208.

[10]All new vehicle models are required to have a consumer information label affixed to them. If NHTSA did not assign a safety rating to a vehicle model through NCAP, the label must disclose this. *See* 15 U.S.C. § 1232; 49 C.F.R. pt. 575, subpt. D. NHTSA also makes NCAP's safety-rating information available on its website.

Figure 1: National Highway Traffic Safety Administration Front- and Side-Impact Crash Tests

Side barrier crash test

Frontal crash test



Side pole crash test

Source: National Highway Traffic Safety Administration. | GAO-23-105595

Vehicle crash test results are influenced by a number of conditions—including the type of dummy, where the dummy is seated, the crash speed, and by the features of the specific vehicle being tested. Testing conditions of FMVSS compliance crash tests are specified in the FMVSS. Design specifications for the types of dummies that manufacturers are required to use in these tests are described in other NHTSA regulations.[11] The purpose of specifying design requirements for the dummy types is to ensure that crash tests of the same vehicle conducted with the same conditions, including the same dummy type, will provide similar results and adequately reflect the vehicle's safety performance.[12] Testing

[11] *See* 49 C.F.R. pt. 572.

[12] *See* 49 C.F.R. § 572.2.

conditions for NCAP crash tests are outlined in NHTSA's periodic updates to NCAP, which are published in the Federal Register.

The use of dummies provides insights into the human body's movement, vehicle performance, and the performance of various safety features during a crash. Dummies are designed to be "biofidelic," meaning that their response in a crash test is intended to replicate the response of a human body. To develop biofidelity, researchers typically conduct tests with cadavers (also known as post-mortem human subjects) to determine the human body's response and resulting injuries in a crash. Researchers then evaluate the extent to which forces on the dummy during the test correspond with actual human injuries in a crash.

Dummies are equipped with instrumentation in various locations—such as head, neck, and chest—that measure acceleration, force, and deflection during a crash test. (See fig. 2.) Those measurements are used with other data, such as from cadaver testing, to determine probabilities of a range of injuries, such as a head injury (as determined by a skull fracture) or a chest injury (as determined by of broken ribs). These probabilities of injury are often expressed on an injury risk curve, which estimates a probability of injury based on a certain amount of force experienced.

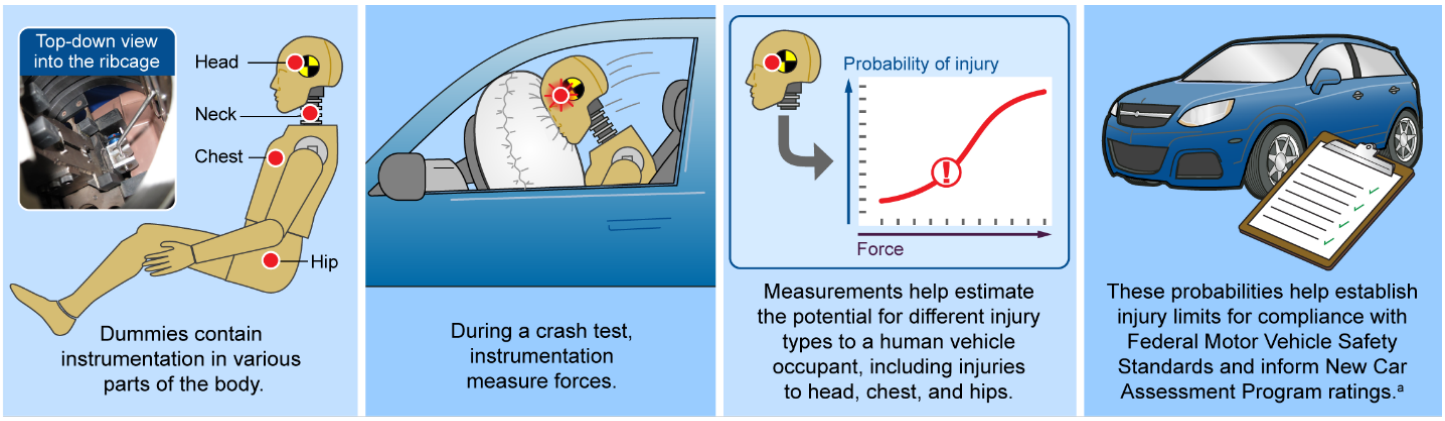
Under the FMVSS, vehicles must meet certain performance requirements for the protection of vehicle occupants in crashes. These requirements are expressed in terms of injury criteria.[13] The measurements collected by the instruments and sensors on the dummy after the crash test are used to calculate the injury criteria in accordance with formulas set by regulation. Vehicles either meet or fail to meet the limits of the injury criteria specified in the standard and, therefore, meet or fail to meet the standard. For example, if the value calculated using the information collected by the sensors in a dummy's head during a crash test exceeds the maximum calculated value for head injury criteria permitted under the relevant FMVSS, a vehicle would fail to meet the standard and thus could not be sold in the U.S. Auto manufacturers may conduct these crash tests, or other testing or analysis, to self-certify FMVSS compliance.

[13]Injury criteria differ based on the type of injury measured, as well as the type of dummy used and other crash test conditions.

NHTSA conducts sample testing of vehicles to verify FMVSS compliance.[14]

For NCAP, injury readings recorded from the dummies in crash tests of a vehicle—which may be conducted by NHTSA or NHTSA contractors—are assessed using injury criteria along with associated injury risk curves. Ultimately, each vehicle receives summary scores, which represent the relative risk of injury for occupants in different seating positions and types of crash tests. These relative risks are then converted to the vehicle's star ratings, so that a lower estimated probability of injury generally corresponds with higher vehicle ratings. (See fig. 2.)

Figure 2: How a Crash Test Dummy Is Used to Estimate Potential Injury in a Front-Impact Crash Test



Source: GAO presentation of information from the National Highway Traffic Safety Administration. | GAO-23-105595

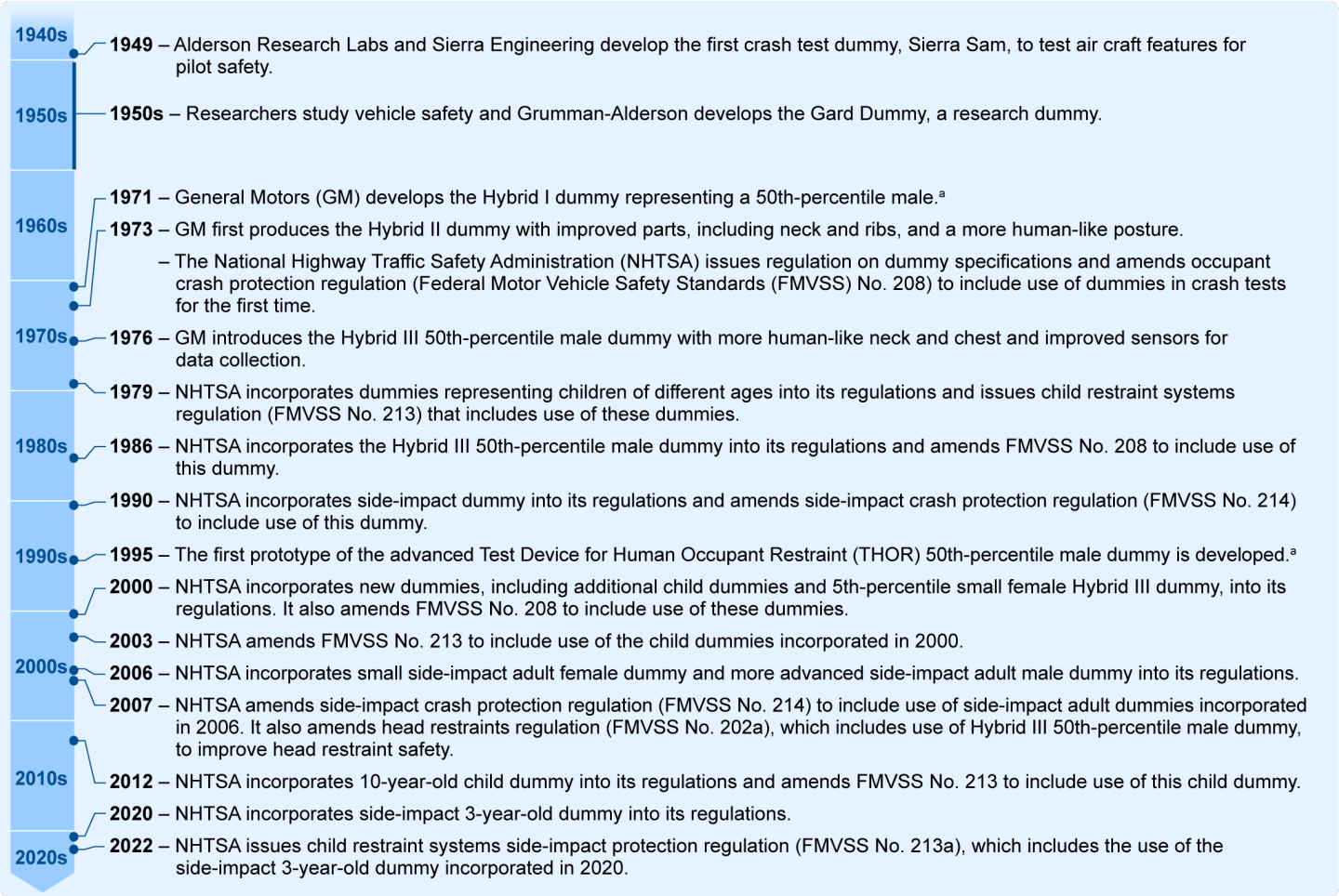
[a]New Car Assessment Program injury criteria are specific to certain injuries, crash tests, and dummies.

The first dummies were developed decades ago. Since then, NHTSA has incorporated multiple dummies into its regulations and established

[14]While NHTSA performs sample testing using FMVSS crash test conditions and procedures, manufacturers are not required by NHTSA or by statute to do the same to self-certify that their motor vehicles or motor vehicle equipment comply with the FMVSS. According to NHTSA, a manufacturer may base its certification on, for example, computer simulations or engineering analyses. However, NHTSA has noted that manufacturers generally do conduct FMVSS crash tests, because conducting the same tests better ensures that the vehicle or equipment will meet FMVSS requirements if and when NHTSA tests it. *See* Notice Regarding the Applicability of NHTSA FMVSS Test Procedures to Certifying Manufacturers, 85 Fed. Reg. 83143, 83144 (Dec. 21, 2020); Federal Motor Vehicle Safety Standards; Child Restraint Systems, Child Restraint Systems-Side Impact Protection, Incorporation by Reference, 87 Fed. Reg. 39234, 39291 n.225 (June 30, 2022).

different crash test types for FMVSS compliance and to inform NCAP ratings. (See fig. 3.)

Figure 3: Key Dates in the Development and Use of Crash Test Dummies



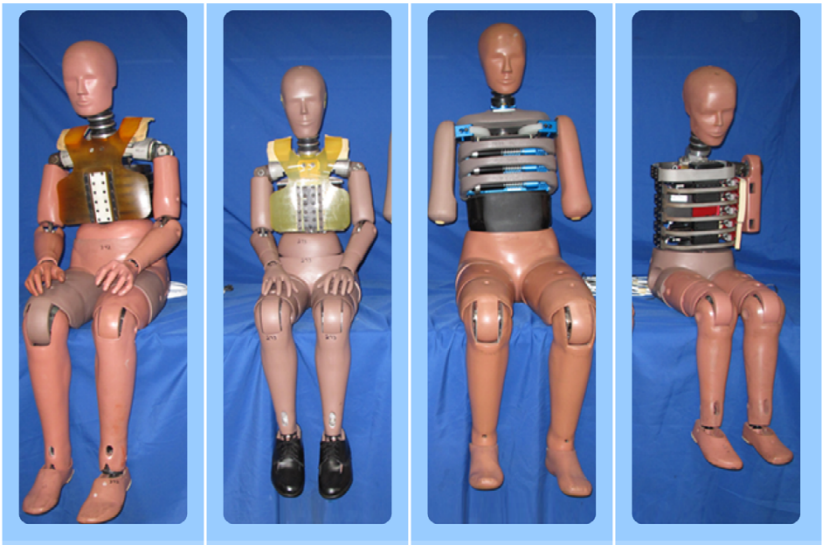
Sources: NHTSA and industry information. | GAO-23-105595

[a]Intended to represent the median height and weight of American adult males.

As of January 2023, four adult-sized dummies—two meant to represent mid-sized males and two to represent small females—are used in FMVSS and NCAP front- and side-impact crash tests (see fig. 4). Child dummies are also used for other safety tests primarily to test child restraint systems such as booster seats, but not vehicles, except to ensure that airbags would not harm children in non-standard seating positions (see app. II). The height and weight of the adult dummies are based on historical percentile data of American adults that are decades old. As of January

2023, the adult dummies used for FMVSS and NCAP tests have been in place for more than 15 years, with the 50th-percentile male front-impact dummy since 1986. NHTSA later added 5th-percentile female dummies to represent smaller occupants, in part to address safety concerns regarding smaller occupants being killed or injured by airbag deployments.

Figure 4: Adult Crash Test Dummies Used for Federal Motor Vehicle Safety Standards Compliance and New Car Assessment Program Ratings as of January 2023



	Hybrid III (M) 50th percentile adult male	Hybrid III (F) 5th percentile adult female	ES-2re 50th percentile adult male	SID-IIsD Small adult female
Dummy name				
Height (feet)	5’9”	4’11”	5’9”	4’11”
Weight (pounds)	171	108	160	97
Used in	• FMVSS front-impact crash tests • NCAP front-impact crash tests • FMVSS rear-impact sled tests (head restraints)	• FMVSS front-impact crash tests • NCAP front-impact crash tests • FMVSS front air bag risk assessment	• FMVSS side-impact crash tests • NCAP side-impact crash tests	• FMVSS side-impact crash tests • NCAP side-impact crash tests • NCAP side air bag risk assessment

FMVSS: Federal Motor Vehicle Safety Standards NCAP: New Car Assessment Program

Source: National Highway Traffic Safety Administration. | GAO-23-105595

NHTSA Regulations Related to the Use of Dummies

Developing a dummy for incorporation into NHTSA's regulations involves an iterative process with a number of steps including determining the dummy's size and weight, testing the dummy in labs and in crash tests, inspecting the dummy, and making changes to the dummy based on the findings of those inspections and tests.[15] Initial development of a new dummy may be started by NHTSA or others, such as dummy manufacturers or researchers.

Before a dummy can be used in crash tests for FMVSS compliance and NCAP ratings, NHTSA incorporates the dummy into its regulations using the same rulemaking process it uses to issue new or amended FMVSS.[16] To do so, NHTSA seeks to ensure that any dummy being considered for incorporation undergoes a rigorous, documented evaluation for its suitability for incorporation. This evaluation includes, at minimum

- a drawing set containing dimensional, mass, and construction specifications of the dummy;
- performance requirements based on test procedures to ensure that the dummy responds accurately and repeatably under specified test conditions for each body region;[17]
- documented procedures for the assembly, disassembly, and inspection of the dummy such that any users performing an FMVSS crash test are able to prepare the dummy before and after testing; and
- documentation that the dummy is sufficiently durable, repeatable, reproducible, and biofidelic to be used as a test instrument, in combination with appropriate injury criteria, to assess the potential for injury in an FMVSS crash test.[18]

[15]D. Rhule, H. Rhule, B. Donnelly, NHTSA, *The Process of Evaluation and Documentation of Crash Test Dummies for Part 572 of the Code of Federal Regulations*, Paper Number 05-0284.

[16]Dummies are incorporated specifically into 49 C.F.R. Part 572.

[17]According to a NHTSA report, repeatable means the extent to which a dummy will provide similar results from multiple crash tests with the same conditions. Reproducible means that multiple, different dummies will provide similar results under multiple crash tests with the same conditions. Rhule et al., *Process of Evaluation and Documentation of Crash Test Dummies.*

[18]Injury criteria are specified in the FMVSS.

Females and Older Individuals Are at Greater Risk in Vehicle Crashes, and Less Is Known about Heavier Individuals and Children

According to NHTSA, vehicle safety has improved over time, in part due to advances in vehicle safety technologies such as airbags. Such safety advances benefit all vehicle occupants. However, according to literature we reviewed and stakeholders we interviewed, certain demographic groups, including females and older individuals, are at greater risk of death and many injury types in vehicle crashes. Less is known about differences in risks for individuals with a higher body mass index (heavier) and children, though those individuals can face some increased injury risks.

Females

Females are generally at greater risk of death and a range of injuries in vehicle crashes than males, but data indicate that the difference in risk is lower for females in newer vehicles. For example, a 2013 NHTSA study analyzed crash data from 1975 to 2010 and estimated that female front row occupants (driver and front row passenger) faced a 17 percent greater risk of death than male front row occupants in vehicle crashes with similar conditions.[19] This study also estimated that females experienced a greater risk than males of a range of injuries including those to the chest (26 percent), neck (45 percent), arms (58 percent) and legs (80 percent).[20] Further, this study estimated that females' greater relative risk of death compared to males decreases with age, and that female drivers have a lower risk of death than male drivers in the oldest group (ages 65 to 96).

In 2022, NHTSA published a study that analyzed newer data and found that while females continue to face a greater risk of death than males, the

[19]NHTSA's estimate for this greater risk was plus or minus 1.5-percent. C.J. Kahane, NHTSA Injury *Vulnerability and Effectiveness of Occupant Protection Technologies for Older Occupants and Women*, DOT HS 811 766 (Washington, D.C.: May 2013).

[20]The estimate was plus or minus 13.6 percent for chest injuries, plus or minus 34.0 percent for neck, plus or minus 20.6 percent for arm, and plus or minus 16.3 percent for leg.

difference is reduced in crashes involving newer vehicles. This study found that this was in part due to improvements in vehicle safety technologies including airbags and advanced seat belts.[21] The 2022 study estimated that female front row occupants have a 19.9 percent greater risk of death than males when in vehicles from model years 1960 to 1999, but that differential in risk falls to 9.4 percent when in vehicles from model years 2000 to 2020, and to 2.9 percent when in vehicles from model years 2015 to 2020.[22]

Physiological reasons might help explain these greater risks for females. For example, NHTSA's 2013 report stated that females have weaker bones and smaller necks (in proportion to head size) than males. It also cited other work stating that the shorter stature of females relative to males may help explain the increased risk of leg injuries, as shorter people may need to sit in a forward position on the seat track, which results in their lower legs being closer to the front of the vehicle. Another study stated that differences between males and females in bone density, bone and ligament geometry, and bone and ligament properties may explain the greater risks faced by females.[23] Five researchers we interviewed also said physiological differences may explain the greater risks to females. However, several stakeholders said that the reasons for the increased risks to females of lower leg injuries are not well understood. One vehicle manufacturer noted that this lack of understanding is in part due to a lack of research with female cadavers.

The types of vehicles and crashes in which females are more likely to be in may also explain some of their increased risks. A study that analyzed data on crashes from 1998 to 2015 found that females tend to drive

21E.Y. Noh, R.J.E. Atwood, M.J. Craig, and E. Lee, NHTSA Female Crash Fatality Risk Relative *to Males for Similar Physical Impacts* DOT HS 813 358 (Washington, D.C.: NHTSA, August 2022). According to NHTSA officials, the agency is working on finalizing a similar report on injury risks.

[22]Specifically, the estimates are 19.9 percent plus or minus 1.3 percent, 9.4 percent plus or minus 2.2 percent and 2.9 percent plus or minus 9.8 percent. This study analyzed data on crashes from 1975 to 2019 involving vehicles with model years from 1960 to 2020 and occupants from 16 to 96 years old.

[23]J. Forman, J. Ash, G.S. Poplin, C.G. Shaw, T.L. McMurry, K. Schmidt, and C. Sunnevang, "Automobile Injury Trends in the Contemporary Fleet: Belted Occupants in Frontal Collisions," *Traffic Injury Prevention*, 20:6 (2019): 607-612.

smaller and lighter vehicles than males.[24] The authors of this study also found that females, when in a crash, are more likely to be in the struck vehicle than the striking vehicle in side- and rear-impact crashes. After accounting for differences, the study concluded that females' increased risk is not as great for all injury types and that differences in risk still exist for moderate lower leg injuries.

Older Individuals

According to studies we reviewed and stakeholders we interviewed, older individuals—who make up a growing percentage of the U.S. population—face greater risk of injury or death in crashes compared to younger individuals, due to weaker bones and other physiological differences.[25] According to NHTSA's 2013 study, a 75-year-old driver is about five times more likely to die than a 21-year-old in a similar crash.[26] This report also found that older occupants, especially those over age 65, are at greater risk of a range of injuries, including to the chest, abdomen, and neck. As with females, safety improvements in newer vehicles may have helped decrease the risk differential for older occupants.

Other studies have also found that older individuals face greater risk in crashes than younger individuals. For example, one study that analyzed data on crashes from 1998 to 2015 reported that vehicle occupants ages 66 and older are at greater risk of many injury types compared to younger occupants, especially chest injuries.[27] This study also reported that the risk of many injury types—primarily leg and head injuries—was reduced for older occupants in vehicles with a model year of 2009 or later.

According to some stakeholders we interviewed and one study we reviewed, older occupants face greater risk of injury or death in part due

[24]M. Brumbelow, and J. Jermakian, "Injury Risks and Crashworthiness Benefits for Females and Males: Which Differences are Physiological?," *Traffic Injury Prevention* (2021).

[25]According to the U.S. Census Bureau, people ages 65 and older made up 16.5 percent of the population in 2020.

[26]The 2013 study notes that the additional risks of aging begin in the early 20s. NHTSA's updated study on risk of death, published in August 2022, did not include analysis of risk of death solely by age. It did examine the risks by age and sex and found that the differential in risk of death for females compared to males is greatest at younger ages.

[27]Forman et al., "Automobile Injury Trends."

to their lower muscle and bone density. In addition, one researcher said older occupants are more likely than younger occupants to be injured in low-speed crashes, which occur more often than high-speed crashes.

Heavier Individuals

Heavier individuals face some greater risks in crashes than those with a lower body mass index. However, the extent of and reasons for these greater risks are not well understood, due in part to limited information on how such individuals' bodies respond in crashes.[28]

One study that analyzed crash data from 1996 to 2008 found that heavier individuals are more likely to die in vehicle crashes and that the risk differential is greater for heavier females than heavier males.[29] Another study based on crash data from 1996 to 2010 found that heavier occupants face overall greater risks of death and higher injury severity.[30] That study also noted that while heavier male occupants were at lower risk of serious head injuries than lower weight male occupants, this was not the case for heavier female occupants.

Studies we reviewed and stakeholders we interviewed provided some insights into the potential reasons for increased risks for heavier occupants in crashes. One study suggested the increased risk of death for heavier occupants is in part because in a crash, it takes longer for the seat belt to engage with their body. This study also suggested increased risk due to higher prevalence of existing health conditions. [31] Another study said poorly fitting seat belts may contribute to increased risks to heavier occupants.[32] One researcher said that the bodies of heavier

[28]Literature we reviewed used varying criteria for "heavier." In interviews with researchers, we asked about the risks to "obese" passengers but did not provide a specific definition for "obese."

[29]For the purposes of this report we use studies' definitions of "obesity" to mean "heavier individuals." This study analyzed risks based on obese individuals with a body mass index of 35 or higher. While this study also estimated that underweight males (defined as those with a body mass index of 18.5) also had a greater risk of death, underweight females did not have a greater risk of death. T.M. Rice and M. Zhu, "Driver Obesity and the Risk of Fatal Injury During Traffic Collisions," *Emerg Med J* 31 (2014): 9–12.

[30]S. Kim, "Sex Specific Effect of Obesity on Serious Head Injury from Motor Vehicle Collisions," SAE Int. J. Trans Safety 8:2 (2020): 95-105. This study defined "heavier" as occupants with a BMI of 30 or higher.

[31]Rice and Zhu, "Driver Obesity and the Risk of Fatal Injury During Traffic Collisions."

[32]Kim, "Sex Specific Effect of Obesity."

individuals are closer to the car door, putting them at risk of greater injury during a side-impact crash. However, one researcher we interviewed said it is difficult to understand the effect of crashes on heavier occupants, in part, because of the way in which an individual heavier person's weight is distributed affects crash outcomes. Specifically, in some cases heavier occupants are more likely to be injured in crashes; in other cases, the extra weight may offer more protection and reduce the risk of injury.

Children

The risks children face in vehicle crashes can vary as children age and their anatomy changes, and vary based on the extent to which children in crashes are properly restrained. According to one researcher we interviewed, it can be difficult to distinguish between the safety provided by the vehicle versus the child restraint (such as a car seat or booster). According to NHTSA, children are much safer in a car crash when properly restrained. NHTSA estimates that, for children less than 1 year old, a child restraint can reduce the risk of fatality by 71 percent in a passenger car and by 58 percent in light trucks (pickup truck, van, or sport utility vehicle). NHTSA also estimates that for children between 1 and 4 years old, restraints can reduce the risk of fatality by 54 percent in passenger cars and 59 percent in light trucks.[33] One study we reviewed also found that children, when in the rear seat and properly restrained, face lower risks than children in the front seat or not properly restrained.[34] However, according to data from the Centers for Disease Control and Prevention, vehicle crashes are the second-highest cause of death for children and adolescents ages 1 to 19. According to NHTSA data, almost 1,100 children ages 14 and younger died in car crashes in 2020.[35]

Children have physiological differences that can affect crash outcomes. For example, according to one researcher, children have more flexible

[33]E. Hertz, NHTSA, *Revised Estimates of Child Restraint Effectiveness,* Report No. DOT HS 96 855 (December 1996).

[34]M. Bauer, L. Hines, E. Pawlowski, J. Luo, A. Scott, M. Garnett, M. Uriell, and J. Pressley, "Using Crash Outcome Data Evaluation System (CODES) to Examine Injury in Front vs. Rear-Seated Infants and Children Involved in a Motor Vehicle Crash in New York State," *Injury Epidemiology* 8:32 (2021).

[35]One reason why vehicle crashes are such a common cause of death for children is that children are less likely to die from other factors, such as heart disease, that may kill adults. According to the Centers for Disease Control and Prevention, firearms were the leading cause of death for children and adolescents ages 1 to 19.

chests than adults, resulting in few chest injuries for children, and that head injuries are the most common injury type for children in crashes. One study we reviewed suggested that this is because children have larger heads compared to the rest of their body.[36] Two researchers and representatives of two vehicle manufacturers said there is a lack of understanding of how children's bodies respond in crashes due to a lack of testing with child cadavers.

Information from Dummies Has Helped Improve Safety and Reduce Some Differences in Risk of Injury and Death among Demographic Groups, but Limitations Remain

Information from Dummies Has Helped Improve Safety for All Vehicle Occupants and Reduce Some Risk Differences

Information provided by dummies used in crash tests has helped improve safety for all vehicle occupants. While the number of deaths in vehicle crashes increased in 2020, instances of injuries and death in vehicle crashes have decreased overall in recent decades. According to NHTSA, information from dummies has helped spur safety improvements for all vehicle occupants, including demographic groups at greater risk. These improvements include more effective restraint systems, such as seat belts and airbags, and vehicle structures that better protect occupants in a crash. For example, NHTSA estimates that between 1975 and 2017, seat belts have saved almost 375,000 lives, and between 1987 and 2018, front airbags have saved about 50,000 lives.

The information provided by dummies in crash tests has also helped reduce the differences in risk of injury or death between females and males, including from airbags and in side-impact crashes. For example:

[36]This paper also found that while kidney injuries from vehicle crashes are rare in children, it is more common than for adults. M. Kurtz; J. Eswara; J. Vetter; C. Nelson; and B. Brandes, "Blunt Abdominal Trauma from Motor Vehicle Collisions from 2007 to 2011: Renal Injury Probability and Severity in Children versus Adults," *The Journal of Urology* 197 (2017): 906-910.

- Smaller vehicle occupants—more likely females—tend to sit closer to the steering wheel and therefore experience greater force when the airbag deploys. NHTSA's requirement to use the Hybrid III 5th-percentile female dummy in FMVSS front-impact crash tests was intended to help ensure that airbags are less likely to injure or kill smaller vehicle occupants. One study showed that females' risk of being severely injured in crashes decreased after NHTSA began requiring the use of this dummy.[37]
- NHTSA found in 2003 that smaller vehicle occupants—again, more likely females—were more likely to be seriously injured in side-impact crashes than mid-size males.[38] To counter this risk, NHTSA began requiring the use of the SID-IIsD 5th-percentile female dummy in the driver's seat for FMVSS side pole crash tests in 2009.[39] According to NHTSA, this change was meant to spur the adoption of side airbags, including ones designed to protect shorter occupants (see fig. 5). A 2022 NHTSA report found that the relative risk of death for females is reduced to close to zero in vehicles with side airbags.[40]

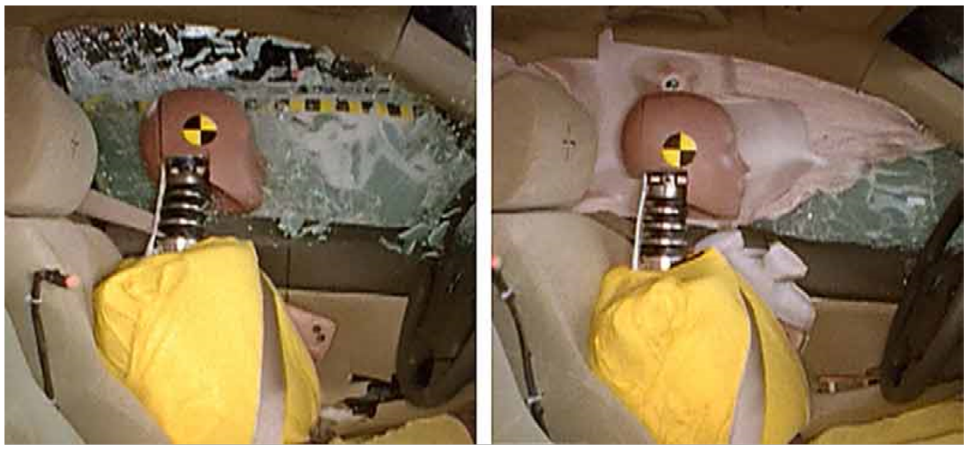
[37]W. Fu, Jaeyoung Lee, and Helai Huang, "How has the injury severity by gender changed after using female dummy in vehicle testing? Evidence from Florida's crash data," *Journal of Transport & Health* 21 (2021) 101073.

[38]R. Radwan Samaha, and Daniel S. Elliott, "NHTSA Side Impact Research: Motivation for Upgraded Test Procedures," In Eighteenth International Technical Conference on the Enhanced Safety of Vehicles, Paper no. 492. 2003.

[39]The side pole test mimics a side-impact crash involving a narrow, fixed object like a utility pole or tree. According to NHTSA, NHTSA selected the 5th-percentile female dummy for the driver's seat because real-world crash data indicated that serious and fatal injuries to near-side occupants—meaning occupants sitting on the side of the vehicle closer to the crash impact—in side-impacts disproportionally affected occupants 5 feet 4 inches or shorter. NHTSA stated these occupants were better represented by the SID-IIsD 5th-percentile dummy.

[40]Noh et al., "Female Crash Fatality Risk Relative to Males."

Figure 5: Side-Impact Crash Test, without and with a Side Airbag



Source: Insurance Institute for Highway Safety. | GAO-23-105595

Information Provided in Crash Tests Is Limited by the Characteristics of Dummies and the Ways They Are Used

The information provided by the dummies currently used by NHTSA—four adult-sized dummies and a range of child-sized dummies—has contributed to vehicle safety improvements. However, the extent to which this information can help further mitigate the greater risks faced by certain demographic groups is limited by the characteristics of dummies and the ways dummies are used in crash tests. (See table 1.)

Table 1: Examples of How Limitations in the Information Provided by Current Crash Test Dummies Relate to Some Demographic Groups

	Limitation	Limitation
Demographic Group	**Characteristics of dummy**	**Use of dummy in National Highway Traffic Safety Administration's (NHTSA) crash tests**
All	• Dummies are a tool to approximate human response in a crash; no dummy will perfectly represent human occupants.	• Crash types may not reflect the accidents in which vehicle occupants are injured or killed, such as offset crashes (where only part of the vehicle comes into contact with the other object). • Federal safety standards and NHTSA's consumer-ratings crash tests have not been regularly updated to include new data about human injury used to interpret information from crash tests.

Demographic Group	Limitation Characteristics of dummy	Limitation Use of dummy in National Highway Traffic Safety Administration's (NHTSA) crash tests
Females	• Female dummy is a scaled version of the 50th-percentile male dummy and does not reflect most female physiological differences. • No sensors to measure forces on the lower legs.	• Female dummy is not used in the driver's seat for one federal safety standards crash test and two of NHTSA's consumer-ratings crash tests. • Estimates about human injury used to interpret information from crash tests are based on data from males and may not reflect female physiology. • Not enough biomechanical research to understand injury risk for females.
Older Individuals	• Single chest sensor may not accurately measure forces.	• Older individuals are more likely to be injured in low speed crashes. No low speed front-impact crash tests in NHTSA's consumer-ratings tests, so restraint systems may not be optimized for lower speeds. • No dummy is used in the rear seat testing for front-impact tests, and rear seat safety has lagged behind front seat improvements. Older occupants may be more likely to be injured in a rear seat than a front seat.
Individuals with higher body mass index	• No dummy represents individuals with a higher body mass index.	• A 95th-percentile male dummy exists but is not incorporated into NHTSA's regulations or used in NHTSA crash tests.
Children	• Child dummies are scaled-down adult dummies and do not reflect physiological differences of children. • Child dummies have less instrumentation than adult dummies to measure potential injury.	• Child dummies are not used in any full-vehicle crash tests. • Estimates about probability of injury used to interpret information from crash tests are based on data from adult males. • Not enough biomechanical research to understand injury risk for children.

Source: GAO analysis of interviews with industry stakeholders and NHTSA officials, relevant publications, and NHTSA research. | GAO-23-105595

Notes: There are four adult sized dummies and a range of child dummies currently used in crash tests. This list of limitations is not necessarily exhaustive and instead provides illustrative examples. In addition, the limitations listed are not mutually exclusive and may also affect the safety of other demographic groups.

Characteristics of Dummies

The characteristics of the dummies currently used in FMVSS and NCAP crash tests limit the extent to which the information that the dummies provide can help mitigate risks to females, older individuals, and heavier individuals. Limiting characteristics of dummies include the lack of different body sizes; the lack of other changes to the dummy to better reflect physiological differences of females and heavier individuals; and the number and location of sensors that collect data during crash tests. While dummies will never perfectly represent all individuals, several stakeholders said the narrow range of dummy characteristics has

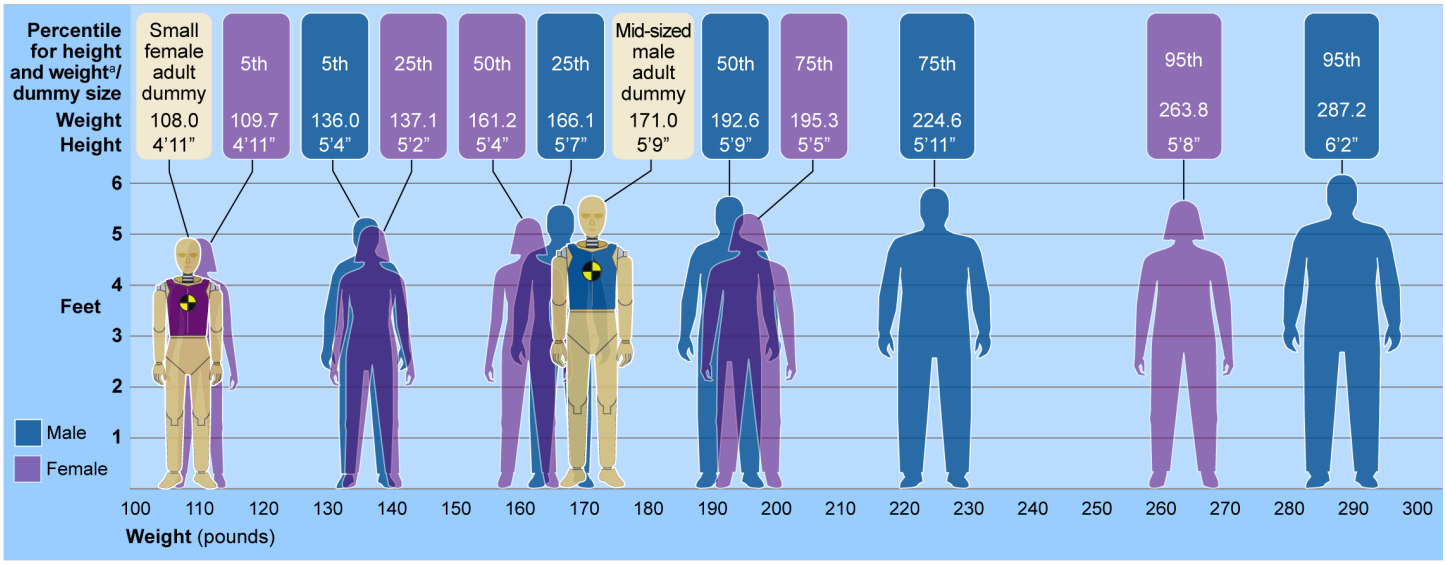
contributed to the greater risk of injury or death for these demographic groups.

Size

Currently, adult dummies with two different body sizes are used in crash tests: a 50th-percentile male and 5th-percentile female. These dummies are meant to provide information to help improve vehicle safety for individuals with a range of heights and weights. For example, some stakeholders noted that using these two sizes of dummies in crash tests best protects individuals whose height and weight are roughly bracketed between the two sizes. However, many individuals fall outside of these brackets—particularly in terms of weight—as Americans have on average gotten heavier over time.

NHTSA officials said the 50th-percentile male dummy is used to represent average-sized adults and the 5th-percentile female dummy is used to represent smaller occupants. However, the 50th-percentile male dummies used in crash tests no longer represents an average U.S. male because American males have gotten heavier, on average, since the dummies were first developed. The average female today weighs 161 pounds and is closer in weight to, and may be represented in terms of weight, by the 50th-percentile male dummy. (See fig. 6.)

Figure 6: Height and Weight of Dummies Used in Vehicle Crash Tests as of January 2023 and of American Adults by Percentile



Source: GAO analysis of information from Centers for Disease Control and Prevention National Center for Health Statistics and the National Highway Traffic Safety Administration. | GAO-23-105595.

[a]By height and weight percentile based on data from 2015 to 2018. These data were reported separately for height and weight percentages, and we combined them into composite individuals for the purposes of this report. The height and weight for the male and female dummies are for the small female and mid-sized male front-impact dummies. The small female and mid-sized male side-impact dummies have the same height but lower weight than their front-impact counterparts.

In addition, no dummy in FMVSS and NCAP crash tests represents heavier individuals, who make up more than 40 percent of the U.S. adult population.[41] A 95th-percentile male dummy exists, with a weight of 223 pounds and height of 6 feet 2 inches, but while it is used for research purposes and by industry, it is not used for any NHTSA crash tests.[42] It has not been evaluated by NHTSA as part of the agency's process to incorporate dummies into federal regulation. Additionally, because this dummy is not obese, based on its size and weight, it may not accurately represent vehicle occupants with higher body mass indices. One researcher described that it is hard to extrapolate the effects of heavier individuals' size or statue from the information collected by current dummies.

Physiology

The female dummies used in FMVSS and NCAP crash tests do not reflect some characteristics specific to female bodies. According to NHTSA, the Hybrid III 5th-percentile female dummy is essentially a scaled-down version of the 50th-percentile male dummy.[43] As a result, the dummy does not reflect most of females' general physiological differences, such as less muscle mass, lower centers of gravity, and wider hips relative to males. Physiological differences can affect how female bodies interact with the seat belt. Two researchers said that poor

[41]According to the Centers for Disease Control and Prevention, from 2017–March 2020, 41.9 percent of Americans were considered obese, which is defined as having a body mass index of 30 or higher.

[42]Representatives of all six automakers we interviewed said they voluntarily use additional dummies, which may include the 95th-percentile dummy, when developing vehicles. For example, some automakers reported using the 95th-percentile dummy to test restraint systems. This use of the dummy does not involve taking measurements from sensors to help estimate the probability of human injury, so it does not offer insights into how heavier individuals respond in crashes.

[43]Scaled-down means that the 5th-percentile female dummy's body parts have the same proportions as the 50th-percentile male dummy. NHTSA officials told us there have been minor modifications made to the 5th-percentile female dummy to better represent female physiology. For example, NHTSA officials said there have been minor modifications to the dummy's breastplate.

seat belt fit may increase the likelihood of lower-leg injury for females and such injuries can have long-term impacts on mobility.

Similarly, physiological differences for heavier individuals can affect seat belt fit because heavier individuals tend to have more body fat in their abdomen. This may put heavier individuals at greater risk of lower-leg injury.[44] The 95th-percentile male dummy may not fully capture potential belt fit issues because it is scaled up from the 50th-percentile male dummy and does not have a higher concentration of body fat in its abdomen.

Sensors

The number and placement of instruments on the dummies currently used limit the extent to which the information they provide can help mitigate risks to certain demographic groups. As these dummies do not have instrumentation to collect data from the lower legs, they do not measure potential lower-leg injuries. This limitation may be of particular importance for females who are at greater risk of these types of injuries, according to most researchers. Two researchers also said that heavier individuals may be at greater risk of lower leg injury. In addition, several stakeholders said the dummies currently used do not accurately measure chest injuries because they have a single chest sensor, which may not accurately gauge the force that a human chest would experience.

Moreover, under the FMVSS, vehicle manufacturers are not required to position the seat belt on a certain place on adult dummies for belted crash tests. NHTSA officials said this is because a prescribed belt location may not be representative of how the seat belt is positioned on a human occupant in that same position. However, if manufacturers choose a position further from the sensor, then the sensor may underestimate the force to a human chest, an outcome that could make manufacturers less likely to adopt advanced restraint technologies that better distribute force.[45] Some stakeholders told us that research shows these advanced

[44]NHTSA, *Effects of Obesity on Seat Belt Fit*, DOT HS 812 164, (Washington D.C.: June 2015).

[45]Regardless of where manufacturers choose to place the belt on the dummy, their vehicles still must comply with the FMVSS. To verify compliance, NHTSA performs sample testing using FMVSS crash test conditions and procedures. According to NHTSA, to the extent that the FMVSS do not require a precise belt location, NHTSA has flexibility to place the belt where the occupant would be expected to place it during its sample testing. This flexibility may affect manufacturers' own decisions on where to position the belt on the dummies in its crash tests and what restraint technologies to adopt.

restraints are associated with a reduced risk of chest injury, to which older occupants are particularly vulnerable.

Use of Dummies in Crash Tests

How dummies are used in crash tests—including the type of crash, where the dummy sits in the vehicle, how far forward or back the seat is positioned, and what injury data are used to interpret information from dummies—also may limit the extent to which the information the dummies provide can help to mitigate risks to certain demographic groups.

Crash Type

The FMVSS require and NCAP uses a limited number of front- and side-impact crash tests that may not fully reflect common, real-world crash types in which vehicle occupants are injured or killed. Three researchers told us that data show real-world occupants experience more injuries and deaths than the dummies used in crash tests predict. For example, NCAP tests do not include offset front-impact crashes—in which only part of the vehicle's front end comes into contact with a striking object, resulting in force being unevenly distributed over a vehicle—which account for many fatalities.

Additionally, there are no low speed (25 miles per hour or less) front-impact crash tests used to inform NCAP ratings.[46] However, according to researchers, many front-impact crashes occur at lower speeds and are more likely to injure older individuals than others who may not be injured in such crashes given their stronger bones. As a result, restraint systems may be optimized for higher-speed crashes and dummies may not collect information that can be used to help encourage technology to reduce chest injuries in lower speed crashes.

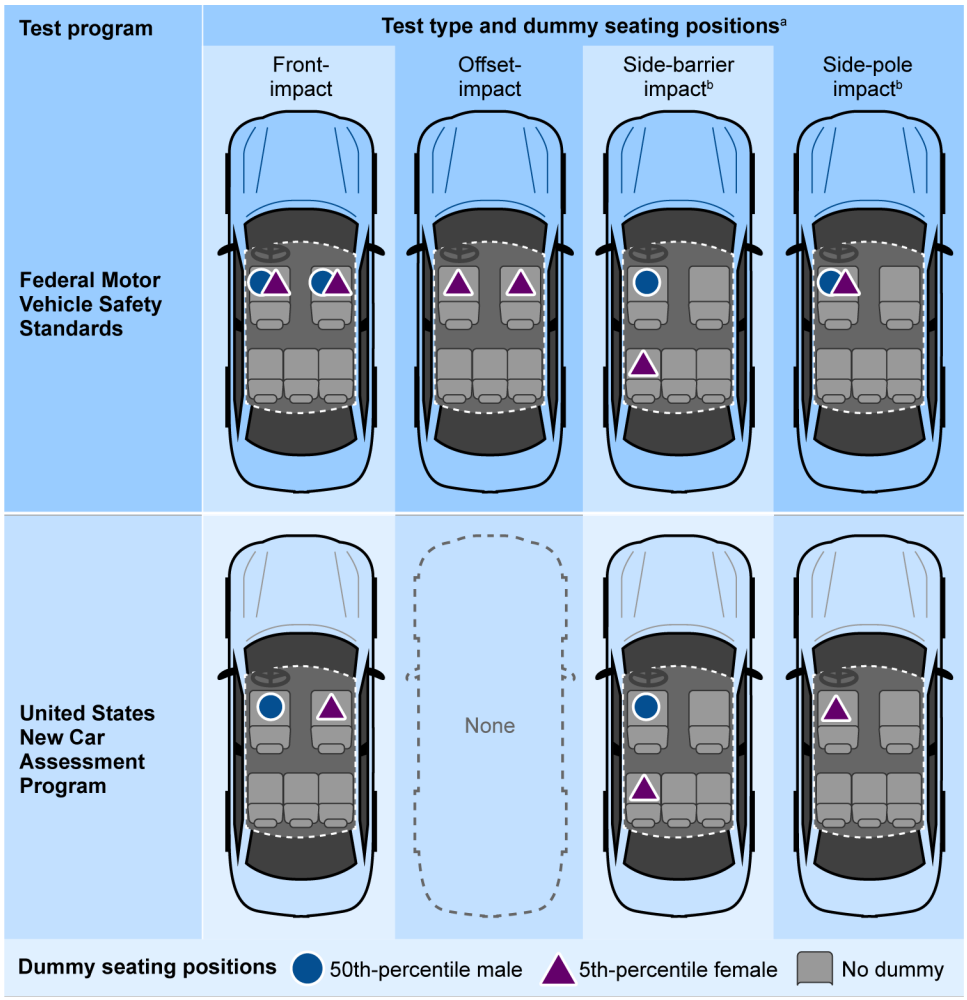
Seating Location

Two of three NCAP crash test types do not use the female dummy in the driver's seat, potentially limiting the extent to which these tests provide information that can help mitigate greater risks faced by female drivers. (See fig. 7.) NHTSA officials said that while developing the current NCAP rating system, NHTSA decided that the agency would put the 50th-percentile male in the driver seat and 5th-percentile female in the front

[46]The FMVSS include a belted full-front impact test at any speed, up to and including 30 miles per hour, an offset front-impact crash test conducted at any speed, up to and including 25 miles per hour, and an unbelted full front-impact crash test that is conducted at any speed between 20 to 25 miles per hour, inclusive. Vehicles must meet applicable performance requirements at every speed within the specified range.

passenger seat. This was because the 50th-percentile male would be representative of an average adult—both male and female—and the 5th-percentile female in the passenger seat would be representative of smaller adults, older children, and young adults. NHTSA officials said they believed this approach to be the best way to ensure safety for a wide range of front row seat occupants by height and weight without adding additional tests, which would require significant resources. However, as females are more likely now to drive vehicles than when the front-impact and side barrier tests were first incorporated into NCAP more than 25 years ago, the information collected by dummies in these crash tests may not adequately reflect the risks to female drivers and, therefore, inform potential safety improvements.

Figure 7: Seating Positions of Dummies in Current Crash Tests



Source: GAO analysis of National Highway Traffic Safety Administration information. | GAO-23-105595

[a]There are additional crash tests required in Federal Motor Vehicle Safety Standards under certain conditions, including optional rollover and lateral moving barrier tests.

[b]The side-barrier crash test mimics a side-impact crash involving another vehicle (e.g., a crash that occurs in an intersection). The side pole test mimics a side-impact crash involving a narrow, fixed object such as a utility pole or tree. The FMVSS provide that side-impact tests can be performed on either side of the vehicle. Dummies are positioned on the side of the vehicle being struck.

Required FMVSS tests use the female dummy in the driver's seat in most crash tests. The female dummy is in the driver's seat in the full front-impact, offset front-impact, and side pole test, but not in the side-barrier test. However, in contrast to NCAP, FMVSS tests are conducted to ensure that vehicles tested meet the federal minimum standards and do not provide comparative information about vehicle safety to consumers.

One stakeholder reported it is easier to meet the FMVSS than to achieve a high NCAP rating.

Dummies are used in the rear seat in one test type: the side-barrier FMVSS and NCAP tests. There are no dummies in the rear seat in any front-impact crash tests even though, according to NHTSA, front-impact crashes were almost 60 percent of all crashes in 2020. Industry stakeholders said that because few crash tests use dummies in the rear seat position, safety improvements for rear seat occupants—frequently children or older individuals—have lagged behind improvements for front seat occupants. Research has shown that rear seats have historically been considered the safest seats in a vehicle, but for most adults, this may no longer be the case.[47] This may have specific implications for certain demographic groups, like older vehicle occupants.

According to representatives from two safety organizations, because of the more limited use of dummies in rear seats during crash tests, rear seats are less likely to have advanced restraint systems. These advanced restraint systems may reduce the risk of chest injury for older occupants. However, two stakeholders and NHTSA reported design for rear seats is challenging because of the wider range of occupants—from infants and children to older individuals—to consider than in front seats.[48]

Seat Track Position

Current crash tests only specify one seat track position—that is, how far forward or back the seat is positioned—based on the dummy being used. Therefore, vehicle manufacturers may optimize vehicle safety for the positions specified in tests even though, in reality, occupants sit in a

[47]D.R. Durbin, J.S. Jermakian, M.J. Kallan, A.T. McCartt, K.B. Arbogast, M.R. Zonfrillo, and R.K. Myers, "Rear seat safety: variation in protection by occupant, crash and vehicle characteristics," *Accident Analysis & Prevention* 80 (2015) 185-192. Elham Sahraei, Kennerly Digges, and Dhafer Marzougui-, “Reduced Protection for Belted Occupants in Rear Seats Relative to Front Seats of New Model Year Vehicles,” *Association for the Advancement of Automotive Medicine*, vol. 54 (2010) 149-158.

[48]NHTSA has published research testing a 6-year-old, 5th-percentile female, 50th-percentile male, and 95th-percentile male dummy to determine what type of occupant protection would serve a wide range of occupants in the rear seat. J. Hu, J. D. Rupp, M. P. Reed, F. Kurt, P. Lange, and A. Adler, "Rear seat restraint optimization considering the needs from a diverse population," *Report No. DOT HS* 812 248.

range of positions.[49] However, varying seat track positions to reflect a range of occupants and seat positions would provide additional data on risks to those occupants that could be reflected in NCAP ratings, in turn informing vehicle safety improvements. Two researchers said varying the seat track positions in crash tests—even by as little as a few inches—would improve safety by making vehicle safety features better designed to protect occupants in a range of seat positions, including females and heavier individuals.

Injury Data and Research

Several stakeholders expressed concern about the validity of currently used injury criteria, which are used to interpret information from dummies. For example, according to one researcher, injury risk curves—on which injury criteria are based—do not reflect the latest real world data. Additionally, because injury risk curves were developed when dummies were developed and have generally not been updated since, they may not accurately reflect the risks for all vehicle occupants.[50] While the basic biomechanical response of human occupants in a crash—and the related risks—have likely not changed over time, NHTSA officials said data from newer research could be used to develop more accurate injury risk curves. As a result, current injury criteria, which inform FMVSS compliance and NCAP ratings, may not provide accurate information about injury risks.

There is also less confidence in injury criteria and the associated injury curves for certain demographic groups, according to several stakeholders, in part because existing injury criteria have been largely informed by research with male cadavers. Injury criteria can be adjusted for sex and age, but there are challenges with these adjusted criteria because there are not always sufficient data about different demographic groups. Several stakeholders and NHTSA officials said there has been

[49]In FMVSS and NCAP tests, the 5th-percentile female dummy is placed at the forward-most seating position (closest to the steering wheel) and the 50th-percentile male dummy is placed at the midpoint of the seat track. According to NHTSA, the seat track positions are appropriate to the size of the dummy being used. Research has shown that most vehicle occupants—regardless of size—do not sit in these two positions. M.A. Manary, M.P. Reed, C. A. C. Flannagan, and L.W. Schneider, "ATD Positioning Based on Driver Posture and Position," *SAE Transactions* 107 (1998) 2911–23.

[50]NHTSA did update the FMVSS injury criteria for the Hybrid III 50th percentile male dummy after its development and incorporation into NHTSA's regulations. In a 2000 final rule amending its occupant crash protection regulation, NHTSA established new neck injury criteria and reduced the amount of allowable chest deflection for this dummy.

less research using female cadavers. Historically, most cadaver research was conducted on subjects that more closely resembled the 50th-percentile male dummy. In addition, there is no research using child cadavers in part because, according to two researchers and two vehicle manufacturers, use of child cadavers is generally considered taboo in research communities. One result of research with limited cadavers is that injury criteria for the 5th-percentile female dummies are largely scaled down from the injury criteria for the 50th-percentile male dummies. Injury criteria for child dummies are also scaled down from adult injury criteria. Accordingly, there are fewer inputs to inform accurate injury criteria for females and children.

Additionally, most researchers, one safety organization, and NHTSA officials said there is not yet enough biomechanical research to understand the underlying reasons why certain demographic groups are at greater risk in vehicle crashes. Researchers said that to develop vehicle safety features, the root cause of differences in risk for certain demographic groups must be understood. According to two researchers, biomechanical research, which also requires cadavers, is expensive: the cost limits the volume of research NHTSA can conduct or support. This gap in information limits development of vehicle safety features to address greater risks for females, heavier individuals, and others.

NHTSA Has Taken Steps to Address Limitations in Information Provided by Dummies, but Gaps Remain

NHTSA Has Conducted Research, Developed Advanced Dummies, and Taken Other Steps to Address Limitations in Information Provided by Dummies

NHTSA has taken or considered taking a number of actions to address limitations in the information provided by dummies in crash tests. Specifically, NHTSA has conducted or supported research, developed and proposed technologically advanced male dummies, developed technologically advanced small female and child dummies, explored simulated crash testing, and requested comments on proposed updates to NCAP crash tests. These actions could help, directly or indirectly, mitigate risks to various demographic groups.

Conducted or Sponsored Research

NHTSA has conducted or supported research to help it better understand risk differences among demographic groups. NHTSA officials told us the agency's research efforts inform regulatory and other decisions. These efforts—some of which are ongoing—include:

- Updating NHTSA's 2013 study on the risk of injury or death for females in traffic crashes. In August 2022, NHTSA published an updated analysis of the risk of death for females, and officials said the agency is completing an updated analysis of injury risks.
- Analyzing data from three different NHTSA databases on real-world crashes to identify risks to demographic groups. According to officials, this study should be published in 2023.
- Partnering with universities on cadaver research to better understand the response of the human body to forces experienced in crashes. According to five of the eight researchers we met with and NHTSA officials, this research is critical for improving dummy biofidelity and injury risk curves.
- Creating models to project injuries in vehicle crashes. The models take into account transportation trends, vehicle purchasing records, and changing populations using historical data. According to NHTSA officials, the models can help inform future research on risks to all vehicle occupants.
- Published a 5-year *Traffic Safety for Older People* plan in 2013.[51] The plan addressed traffic safety concerns for older people, as well as improvements to vehicle safety that take into account the physiological differences that put older individuals at greater risk. The plan also identified the need to gather more data on risks to older individuals and on the extent to which vehicle restraints protect them. Officials told us NHTSA does not intend to update the plan.

Developed Technologically Advanced Male Dummies

Since the mid-1980s, NHTSA has been involved in developing a technologically advanced front-impact crash test dummy (known as THOR 50th-percentile male), which has more instrumentation and sensors than the existing Hybrid III 50th-percentile male dummy (see fig. 8). NHTSA officials told us that the THOR 50th-percentile male dummy is

[51]NHTSA. *Traffic safety for older people — 5-year plan*. Report No. DOT HS 811 837. (Washington, D.C.: December 2013).

more biofidelic because it can capture occupant movement in multiple directions and because its sensors better reflect human responses to crash conditions.[52] However, like the Hybrid III 50th-percentile male dummy, the THOR 50th-percentile dummy has a height and weight based on decades old data.

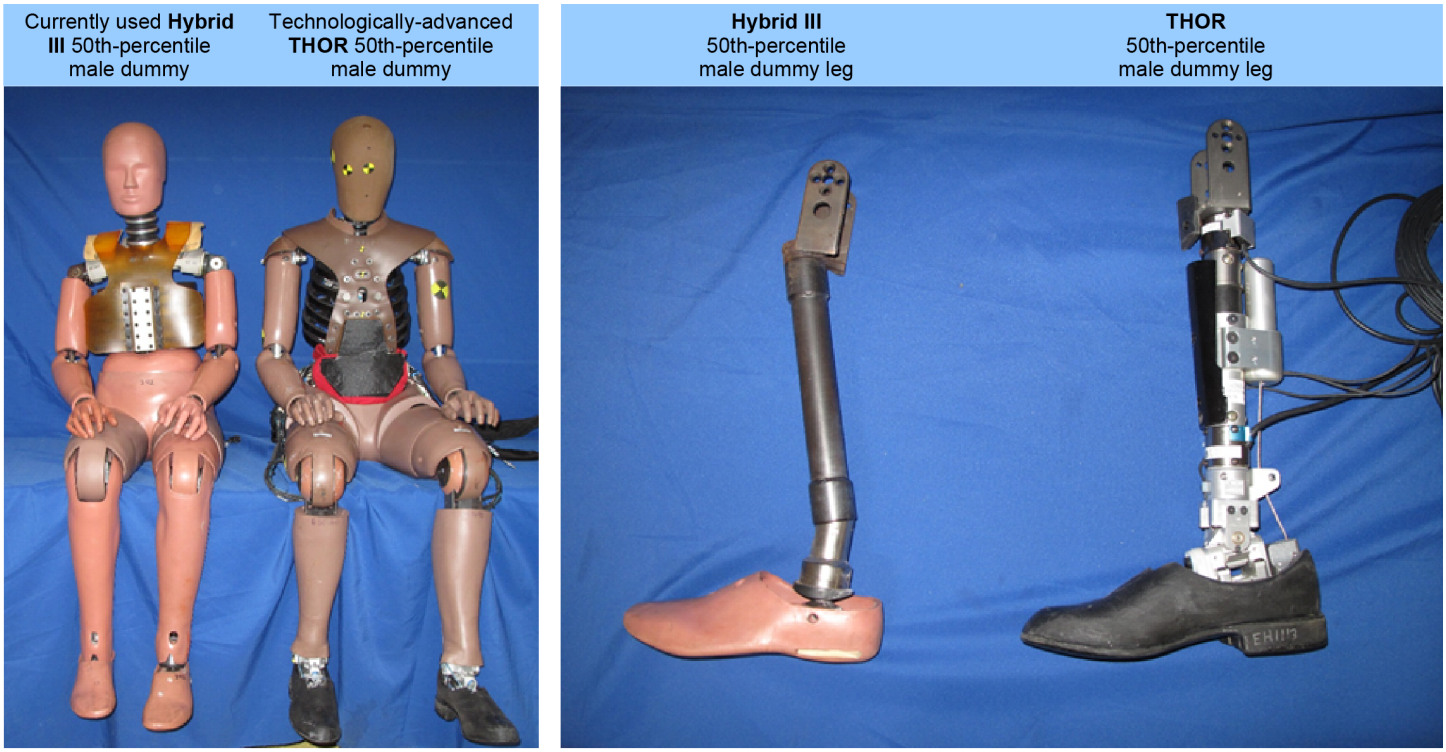
NHTSA first requested comments on the potential use of this technologically advanced male dummy, as well as another technologically-advanced male dummy for side impact crashes (WorldSID 50th-percentile male), in NCAP tests in 2013.[53] According to the Fall 2022 Unified Agenda of Regulatory and Deregulatory Actions, NHTSA is planning to issue a notice of proposed rulemaking to incorporate these technologically advanced dummies, which have enhanced instrumentation and biofidelity.[54] According to NHTSA officials, information from advanced male dummies will enable better evaluation of vehicle safety and spur the development of safer vehicles that benefit all occupants, including females and others at greater risk.

[52]Representatives from one automaker we met with said their company has used the THOR 50th-percentile male dummy to improve restraint systems and advanced airbags during vehicle development.

[53]New Car Assessment Program (NCAP), 78 Fed. Reg. 20597 (April 5, 2013). Euro NCAP began using a version of the THOR 50th-percentile male dummy with non-instrumented legs in 2020.

[54]*See* DOT/NHTSA, Part 572 THOR-50M Crash Test Dummy, RIN 2127-AM20, Unified Agenda of Regulatory and Deregulatory Actions (Fall 2022); DOT/NHTSA, Part 572 WorldSID-50M Crash Test Dummy, RIN 2127-AM22, Unified Agenda of Regulatory and Deregulatory Actions (Fall 2022). The weights of the technologically advanced male dummies are not representative of the current weight of 50th-percentile adult males.

Figure 8: Differences in Instrumentation between Technologically Advanced Crash Test Dummies and Currently Used Crash Test Dummies



Source: National Highway Traffic Safety Administration. | GAO-23-105595

According to NHTSA officials, the agency is finalizing work on documentation to show the information provided by the advanced male dummies is objective, repeatable, and reproducible before NHTSA issues a notice of proposed rulemaking for each dummy.[55] The officials also noted that the process to ensure that a new dummy meets those criteria and provides clear safety benefits requires significant testing and demonstration and, therefore, is time consuming.

Developed Technologically Advanced Small Female and Child Dummies

NHTSA has also been involved in developing technologically advanced 5th-percentile front- and side-impact female dummies. Officials told us the front-impact dummy (THOR 5th-percentile female) is more biofidelic than the currently used dummy, since it was developed using female cadavers

[55]Euro NCAP began using a version of the THOR 50th-percentile male dummy with non-instrumented lower legs in 2020.

and is not simply a scaled-down version of the male dummy. In a September 2022 interim report to Congress, NHTSA stated it is evaluating the THOR 5th-percentile female dummy's biofidelity and durability and developing injury criteria and documentation needed to incorporate the dummy into its regulations.[56] According to the Fall 2022 Unified Agenda of Regulatory and Deregulatory Actions, NHTSA is planning to issue a notice of proposed rulemaking in 2023 to incorporate the THOR 5th-percentile female dummy into its regulations.[57] For the small female side-impact dummy, NHTSA expects, in 2025, to complete the documentation needed to decide whether to propose the dummy's incorporation into its regulations.

In November 2020, NHTSA issued a final rule incorporating a technologically advanced child dummy (Q3s), representing a 3-year-old child, into its regulations.[58] This dummy has been specified for use in a new FMVSS side-impact sled test required for child restraint systems for children weighing up to 40 pounds or for children whose height is less than about 3.5 feet tall.[59] NHTSA is also working to develop a larger technologically advanced child dummy representing a 10-year-old child—the Large Omnidirectional Dummy—to better address child injuries. (See fig. 9.) NHTSA expects to complete the documentation of this dummy's development in 2023.

[56]NHTSA, *Interim Report to Congress, Crash Test Dummies (*September 2022).

[57]DOT/NHTSA, Part 572 THOR 5th Female Crash Test Dummy, RIN 2127-AM56, Unified Agenda of Regulatory and Deregulatory Actions (Fall 2022).

[58]The effective date of this final rule was January 4, 2021. Anthropomorphic Test Devices; Q3s 3-Year-Old Child Side Impact Test Dummy; Incorporation by Reference, 85 Fed. Reg. 69898 (Nov. 3, 2020).

[59]Sled tests for child restraint systems is where a child restraint system is attached to bench that is mounted to a platform (known as a sled). These sleds may be accelerated and decelerated at a speed that replicates crash forces, or sleds may be equipped with a vehicle door and struck from the side by a barrier representing another vehicle. Sled tests may be used to test vehicle components, such as restraint systems or airbags, without full-scale crash tests using vehicles. In June 2022, NHTSA issued a final rule establishing FMVSS No. 213a, which specifies performance requirements for certain child restraint systems in side-impact sled tests. Federal Motor Vehicle Safety Standards; Child Restraint Systems, Child Restraint Systems-Side Impact Protection, Incorporation by Reference, 87 Fed. Reg. 39234 (June 30, 2022). This test replicates a vehicle moving at 30 miles per hour striking the side of another vehicle moving at 15 miles per hour.

Figure 9: Development of the Large Omnidirectional Child Dummy

Source: Center for Child Injury Prevention Studies, Children's Hospital of Philadelphia Research Institute, and The Ohio State University. | GAO-23-105595

Explored Simulated Crash Testing

What are crash test simulations?

Crash test simulations are virtual recreations of crash tests that use computer models of human bodies and of vehicles. Simulations are capable of calculating the movement of the human body during a vehicle crash, the onset and severity of potential injury, and the vehicle's ability to protect its occupants. To make these calculations, simulations take into account selected assumptions and the geometry and forces associated with crashes.

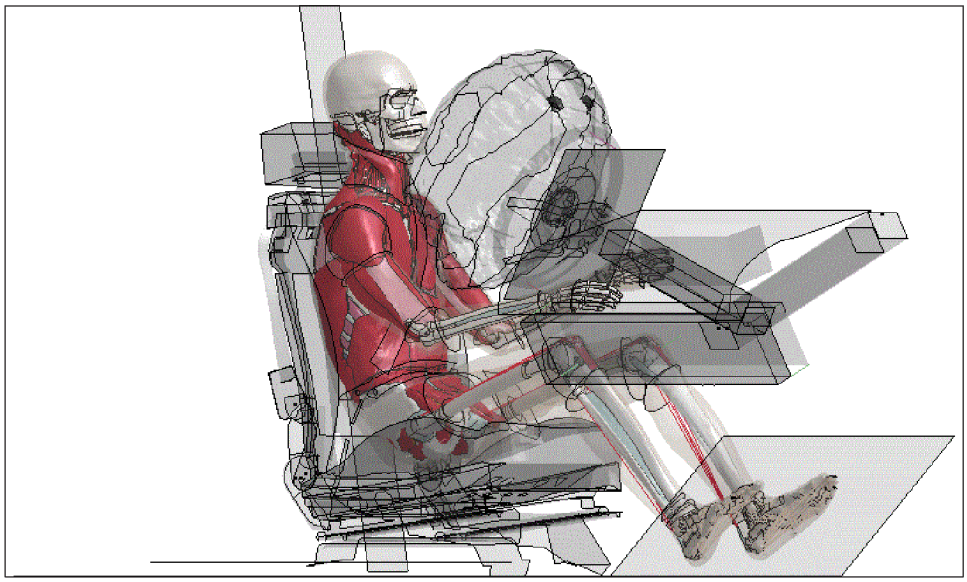
Simulations can use a range of human body models to show how demographic differences—such as height, weight, and body type—affect crash outcomes. Before use in simulations, both human body models and vehicle models must be validated with physical tests to confirm their accuracy and objectivity.

Most stakeholders we interviewed consider simulation as a complement to—not a replacement for—physical crash tests. Two researchers and two industry associations view simulation as a growing field and are working to develop more sophisticated models. Additionally, one automaker we met with told us they use virtual vehicle models extensively when developing new makes and models.

Source: GAO. | GAO-23-105595

NHTSA has evaluated the potential to combine computer models of the human body and of vehicles to simulate crash tests (see fig. 10).[60] NHTSA officials said the agency uses simulations for research and other purposes, including to develop and evaluate test methods and to estimate safety benefits for many of NHTSA's research activities. Computer modeling has been particularly beneficial for estimating safety benefits when little data are available.[61] NHTSA uses simulation to evaluate the feasibility, effectiveness, and potential limitations of proposed test procedures and safety countermeasures. For example, simulation has been used for a range of projects including vehicle crashworthiness and seat belt design. [62]

Figure 10: Example of Human Body Modeling in a Vehicle Crash Simulation



Source: National Highway Traffic Safety Administration. | GAO-23-105595

[60]NHTSA is one of the sponsors of the Global Human Body Models Consortium, along with several automakers and one supplier of vehicle parts. Created in April 2006, the mission of the consortium is to develop and maintain models capable of simulating the complex movement of the human body during a vehicle crash, and of predicting the onset and severity of potential injury. The consortium has developed several virtual human body models, including of adult males and females of various sizes and of a 6-year-old pedestrian.

[61]S. Summers, and T. Hollowell, *Crashworthiness Modeling Activities*, National Highway Traffic Safety Administration, Paper no. 251 (Washington, D.C.).

[62]EuroNCAP currently uses simulation to assess pedestrian safety.

According to NHTSA officials and most stakeholders, simulation can assess a wider range of vehicle occupants and crash scenarios in a more cost-effective manner than physical crash testing. Some researchers said simulation has shown that different body types react differently under crash conditions, underscoring the need to test vehicles for a broader range of occupants.

However, NHTSA officials noted challenges in using crash test simulation for FMVSS compliance and to inform NCAP ratings. For example, for NHTSA to perform a crash test simulation, vehicle manufacturers would need to provide the agency with vehicle model information. Officials said manufacturers might not be willing to share this proprietary information. Moreover, even if vehicle manufacturers did provide this information, NHTSA would not be able to verify its accuracy. In addition, some stakeholders said complex simulations are still in development, because the models must demonstrate feasibility and reliability and be validated with physical tests in order to produce accurate results.

Requests for Comments on Updates to NCAP

NHTSA has requested comments on possible changes to NCAP that could help address the limitations in the information provided by dummies. However, NHTSA has not yet implemented any of these changes.

- **Use of a large male dummy.** NHTSA requested comments in 2007, in part, on whether there are other dummies NHTSA should consider using in NCAP.[63] Some public comments the agency received suggested the use of a 95th-percentile male dummy in front-impact NCAP crash tests. In its 2008 NCAP update, NHTSA stated that it would not do so at that time due to the need for additional research and testing with the dummy. NHTSA sought additional comments on the topic in 2013.[64]
- **Ratings for specific demographic groups.** NHTSA, in 2013, requested comments regarding developing a ‘‘silver car’’ rating for NCAP, which would provide crash safety information for older vehicle

[63]The New Car Assessment Program; Suggested Approaches for Enhancements, 72 Fed. Reg. 3473 (Jan. 25, 2007).

[64]Consumer Information; New Car Assessment Program, 73 Fed. Reg. 40015 (July 11, 2008); New Car Assessment Program (NCAP), 78 Fed. Reg. 20597 (Apr. 5, 2013).

occupants.[65] According to NHTSA documents, older consumers could use NCAP's silver car rating information to help them select and purchase vehicles that would be potentially safer for them. For example, vehicles with features of particular benefit to older occupants—such as inflatable seat belts or technologies that help prevent mistaking the gas pedal for the brake pedal—could receive high silver car ratings.

- **New crash test configurations.** NHTSA requested comments in 2015 and 2022 on adding a new oblique front-impact crash test for NCAP, which is a type of crash with a high fatality rate.[66] NHTSA last updated NCAP crash test configurations in 2008, when it added the oblique side pole test.[67]
- **Additional seating locations for dummies.** In 2013, NHTSA requested comments on the feasibility of conducting crash tests with advanced child dummies in the rear seat, which would help inform a ‘‘family star rating.”[68]

Gaps Exist in NHTSA's Efforts to Address Limitations in the Information Provided by Dummies

While NHTSA has taken steps to address limitations in the information provided by dummies, gaps remain that may limit DOT's ability to achieve its strategic goals related to safety and equity. The Department's fiscal years 2022 to 2026 strategic plan includes the goal of making the U.S. transportation system safer for all people, noting the need to "reduce racial and gender inequities in transportation-related health and safety outcomes." Further, we have previously identified essential elements of risk management to better ensure agencies meet their goals, including that agencies should:

[65]New Car Assessment Program (NCAP), 78 Fed. Reg. 20601.

[66]New Car Assessment Program, 80 Fed. Reg. 78521 (Dec. 16, 2015); New Car Assessment Program, 87 Fed. Reg. 13452 (Mar. 9, 2022). An oblique crash test for front-impacts includes where a vehicle is struck (by another vehicle or barrier) at an angle that is not perpendicular. An oblique test induces movement that is omni-directional (i.e., including front, back, side, and diagonal movement).

[67]Consumer Information; New Car Assessment Program, 73 Fed. Reg. 40015 (July 11, 2008).

[68]New Car Assessment Program (NCAP), 78 Fed. Reg. 20602.

- respond to risks to achieving organizational goals;
- monitor risks, using milestones and timelines to respond in a timely manner; and
- communicate and report about risks to external stakeholders to increase transparency.[69]

Our review identified gaps in NHTSA's efforts that are not consistent with these elements, including incomplete responses to risks, missed milestones, and limited communication. (See table 2.)

Table 2: Gaps in the National Highway Traffic Safety Administration's (NHTSA) Efforts to Address Risks to Demographic Groups in Crashes with Good Risk Management Practices

Demographic group	NHTSA's efforts	Gaps
All	Developing technologically-advanced male dummies and working on proposing to incorporate into regulations	Missed milestones Limited communication
All	Established new crash test configurations for NCAP	Incomplete response to risks Limited communication
Females	Developing technologically advanced small female dummies and working on proposing to incorporate into regulations	Incomplete response to risks
Older Individuals	Issued a 5-year plan for older individuals in 2013	Incomplete response to risks Limited communication
Older Individuals	Proposed an NCAP rating for older individuals in 2013	Limited communication
Heavier Individuals	Considered the use of the 95th-percentile male dummy in NCAP crash tests	Incomplete response to risks Limited communication
Children	Issued side-impact protection regulation for child restraint systems	Missed milestones
Children	Proposed including child dummies in the rear seat in NCAP crash tests	Incomplete response to risks

Source: GAO analysis of NHTSA information. | GAO-23-105595

Incomplete Response to Risks

For at least two decades, NHTSA has identified greater risks faced by certain demographic groups but has taken incomplete action in response to limitations in the information provided by dummies to address these risks.

For example, in 2002, NHTSA acknowledged that females were at greater risk of lower-limb injuries in vehicle crashes and of long-term

[69]GAO, *Enterprise Risk Management: Selected Agencies Experiences Illustrate Good Practices in Risk Management*, GAO-17-63 (Washington, D.C.: Dec. 1, 2016).

impairment frequently associated with such injuries.[70] Further, since 2013, NHTSA has been aware that females are at greater risk of injury or death in crashes. While NHTSA has conducted research to understand these risks and worked to develop technologically advanced female dummies, NHTSA does not anticipate initiating the rulemaking process to incorporate advanced female dummies for front impact until 2023 and for side impact until 2025. Representatives of two safety organizations we spoke with expressed concern that NHTSA has prioritized the initial development of advanced male over advanced female dummies. NHTSA officials told us it prioritized the development of the advanced 50th-percentile male because men have made up the majority of fatalities. In addition, officials noted that it was a challenge to modify the instruments and sensors to fit in the smaller body of the female dummy.

Similarly, older and heavier vehicle occupants face higher risks, but NHTSA's efforts in these areas remain incomplete. For instance, NHTSA reported in 2013 that older occupants are at higher risk of death and injury in vehicle crashes; however, its research plan that was focused on older occupants lapsed in 2018 with no further action. In August 2022, NHTSA officials told us they do not expect to issue another research plan on older occupants. In addition, NHTSA has taken limited steps beyond research to address increased risks to heavier individuals.

Further, while NHTSA has considered using child dummies and restraint systems in the rear seats during front-impact NCAP tests, the agency has not completed action on this effort. In 2005, NHTSA published a final decision notice that a rating program based on child restraint system testing in rear seats would not provide practicable, readily understandable, or meaningful information to consumers.[71] NHTSA raised this topic again in 2013 when it requested comments on the feasibility of conducting crash tests with advanced child dummies in the rear seat, which would help inform a ‘‘family star rating." NHTSA has not followed up on that effort and, as of January 2023, there are no full-vehicle NCAP

[70]In a 2002 advance notice of proposed rulemaking, NHTSA stated that the agency believed there is considerable merit in using crash test dummies with instrumented lower legs to either assess the risk of injury or mitigate the number or severity of these injuries. Anthropomorphic Test Devices; Instrumented Lower Legs for Hybrid III-50M and -5F Dummies, 67 Fed. Reg. 22381 (May 3, 2002). NHTSA has not taken further action in this rulemaking. NHTSA officials said the agency has since pursued using the THOR dummy, which includes instrumented lower legs.

[71]Frontal New Car Assessment Program, 70 Fed. Reg. 29815 (May 24, 2005).

crash tests that assess the protection the vehicle provides to properly restrained children.

Several stakeholders told us there may be additional opportunities to address risks that NHTSA could consider, including incorporating new crash test configurations. For example, Euro NCAP uses child dummies in the rear seats in its crash tests while NHTSA crash tests do not. By doing this, Euro NCAP crash tests collect additional data that may be able to inform additional vehicle safety improvements.

Missed Milestones

While NHTSA has set some milestones, it has missed milestones for a number of efforts. For example, in 2013, when NHTSA first proposed the use of front- and side-impact advanced adult male and small adult female dummies for NCAP crash tests, the agency stated it expected to make decisions on the front-impact dummies in 2013 and 2014, respectively.[72] In its 2015 request for comments, NHTSA indicated that it would adopt the advanced male dummies for NCAP but stated that it had yet to acquire the front-impact advanced female dummy to research and test and that the side-impact advanced female dummy was still under development and testing.[73]

More recently, in spring 2020, NHTSA published notices that it expected to propose the incorporation of the two advanced male dummies into its regulations.[74] The expected timeframes for issuing a notice of proposed rulemaking were September 2020 and November 2020. As of January 2023, NHTSA has not issued these notices of proposed rulemaking. According to NHTSA, developing new dummies to ensure their biofidelity and objectivity is a challenging and time-consuming process. In addition, several stakeholders cautioned against implementing changes to dummies without a clear understanding of how those changes would

[72]New Car Assessment Program (NCAP), 78 Fed. Reg. 20597, 20601-20603 (Apr. 5, 2013).

[73]New Car Assessment Program, 80 Fed. Reg. 78523, 78535, 78537 (Dec. 16, 2015). In its September 2022 Interim Report to Congress, NHTSA indicated that the front-impact advanced small female dummy was procured and that it is currently developing and evaluating it.

[74]Part 572 THOR-50M Crash Test Dummy, RIN: 2127-AM20, Unified Agenda of Regulatory and Deregulatory Actions (Spring 2020); Part 572 WorldSID-50M Crash Test Dummy, RIN: 2127-AM22, Unified Agenda of Regulatory and Deregulatory Actions (Spring 2020).

inform improvements to vehicle safety. For example, one stakeholder said that having more sensors on a dummy, which will produce additional data, does not necessarily benefit vehicle safety if there are not meaningful ways to use the data.

NHTSA has also missed other deadlines related to completing rulemakings.[75] For example, on June 30, 2022, NHTSA issued a final rule establishing FMVSS No. 213a, which specifies performance requirements for certain child restraint systems in side impact crash tests, to fulfill a statutory mandate.[76] However, this statutory mandate required NHTSA to issue a final rule no later than July 6, 2014, which NHTSA missed by almost 8 years. NHTSA also had a statutory deadline to submit a report on dummies and related equity issues to certain congressional committees. NHTSA submitted the report in October 2022, missing the statutory deadline by about 8 months.[77]

Missed milestones may affect vehicle safety improvements. Several stakeholders said that because of NHTSA's missed milestones, they do not know when to expect rulemakings related to dummies and updates to NCAP. For example, one automaker described NHTSA's incorporation of the THOR 50th-percentile male dummy into its regulations as a moving target. One automaker we met with noted there are long lead times to develop vehicles, and another automaker told us that delays in NHTSA rulemakings may push anticipated vehicle safety improvements out a number of years. In addition, one stakeholder said that missed milestones might undermine relationships with external stakeholders, while another said that missed milestones erode confidence that NHTSA is going to follow-through on its proposals.

[75]Additionally, in prior work we have reported that in other contexts, NHTSA has missed deadlines when completing statutorily required rulemakings and reports. See GAO, *Traffic Safety: Implementing Leading Practices Could Improve Management of Mandated Rulemakings and Reports*, GAO-22-104635 (Washington, D.C.: Apr. 26, 2022).

[76]Federal Motor Vehicle Safety Standards; Child Restraint Systems, Child Restraint Systems-Side Impact Protection, Incorporation by Reference, 87 Fed. Reg. 39234. The Moving Ahead for Progress in the 21st Century Act required NHTSA to amend FMVSS No. 213 to improve the protection of children seated in child restraint systems during side impact crashes, no later than 2 years after the act's enactment. Pub. L. No. 112-141, § 31501(a), 126 Stat. 405, 773-774 (2012).

[77]*See* Infrastructure Investment and Jobs Act § 24221(b). *Interim Report to Congress, September 20*22, Crash Test Dummies.

Limited Communication

NHTSA has not communicated its reasons for letting some of its efforts to address the limitations in information provided by dummies lapse, or for missing some of its milestones. For example, NHTSA has not clearly communicated why it has not yet issued notices of proposed rulemaking to incorporate technologically advanced male dummies into its regulations, even though the agency has indicated its intent to do so. NHTSA also did not communicate that it would not release another safety plan for older individuals. In addition, NHTSA has not communicated why it has not yet pursued certain proposals for NCAP, including using a 95th-percentile male dummy, new crash test configurations, the potential silver car NCAP rating, and a family rating system. We have previously reported that NHTSA has not consistently reported the status of rulemakings.[78] Additionally, several stakeholders we met with expressed concern with NHTSA's lack of communication regarding its proposals. For example, one stakeholder said that NHTSA is not transparent and that it is unclear how the agency makes final decisions.

NHTSA Does Not Have a Plan for Comprehensively Addressing the Gaps in Its Efforts

NHTSA officials cited several reasons for the gaps discussed above, including challenges associated with research and the rulemaking process. While the factors cited by NHTSA do contribute to these gaps, NHTSA also does not have a plan that comprehensively addresses existing risks to demographic groups and limitations in the information dummies provide, and that has milestones, timelines, and a strategy for communication with stakeholders. We have previously reported that developing action plans including these elements can help agencies better address risks.[79] Developing and communicating a plan to more comprehensively address the limitations in information provided by dummies would better enable NHTSA to improve vehicle safety for females, older individuals, and other occupants who continue to be at greater risk of injury or death from crashes.

In discussing planning documents with NHTSA, officials pointed to the *Equity in Crashworthiness Safety Research Plan*, issued in January 2022, as a plan guiding agency efforts on addressing dummy issues. This

[78]GAO-22-104635.

[79]GAO-17-63.

document lays out information on relevant NHTSA efforts related to female crash safety. However, it does not address any other demographic groups at increased risk of injury or death in crashes, such as older or heavier individuals. Further, it does not contain information on milestones.

Developing and communicating a plan that more comprehensively addresses areas of risk, as well as including milestones and mechanisms for communication, would help NHTSA better address gaps to achieving DOT's equity and safety-related goals. This would enhance safety for vehicle occupants, such as females and older individuals, who continue to be at greater risk of injury or death from crashes. Without such a plan, NHTSA may miss opportunities to better address limitations in the information provided by dummies. While a plan may not enable NHTSA to address these limitations any faster, it would set milestones and timeframes to help NHTSA manage the duration of its efforts and improve communication to improve the transparency of its efforts.

Conclusions

Vehicles and the safety features they offer—tested and refined by information provided by crash test dummies—play an important role in reducing risk of death and injury in crashes for all vehicle occupants. However, some demographic groups, including females, older individuals, and individuals with a higher body mass index, continue to face greater risks of injury or death. The characteristics and use of current dummies limit the extent to which the information they provide can reduce those greater risks. For example, the absence of lower leg instrumentation and reflection of female physiology in current dummies, how current dummies are used in crash tests, and limited understanding of how female bodies respond in vehicle crashes may limit the extent to which information collected from dummies in crash tests can mitigate risks for females. NHTSA has taken some actions to address these limitations, but its efforts have been incomplete in responding to existing risks, missed milestones, or not been well communicated. A comprehensive plan to respond to these risks, including timeframes and mechanisms for communication, would better enable NHTSA to improve safety for all, including those who face greater risks, and provide Congress, the public, and other stakeholders with information to hold NHTSA accountable on progress.

Recommendation for Executive Action

The Administrator of NHTSA should develop and communicate a plan to address limitations in the information dummies provide related to the greater risks certain demographic groups face in vehicle crashes. Such a plan should detail how efforts will respond to risks, set milestones for activities, and establish mechanisms to communicate decisions and progress. (Recommendation 1)

Agency Comments

We provided a draft of this report to the Department of Transportation for review and comment. The Department of Transportation provided a letter, reproduced in appendix III, in which it agreed with our recommendation. It also provided technical comments that we incorporated as appropriate.

We are sending copies of this report to the appropriate congressional committees, the Secretary of Transportation, the Administrator of the National Highway Traffic Safety Administration, and other interested parties. In addition, the report is available at no charge on the GAO website at https://www.gao.gov.

If you or your staff have any questions about this report, please contact us at (202) 512-2834 or repkoe@gao.gov. Contact points for our Offices of Congressional Relations and Public Affairs may be found on the last page of this report. GAO staff who made key contributions to this report are listed in appendix IV.

Elizabeth Repko
Director, Physical Infrastructure Issues

Appendix I: List of Industry Stakeholders Interviewed

Table 3: List of Stakeholders Interviewed

Category	Category information
Researchers	Drs. Jason Forman, Greg Shaw, Matthew Panzer, Center for Applied Biomechanics, University of Virginia
Researchers	Dr. John Bolte, Injury Biomechanics Research Center, The Ohio State University
Researchers	Dr. Kristy Arbogast, Center for Injury Research and Prevention, Children's Hospital of Philadelphia
Researchers	Drs. Matthew Reed, Jingwen Hu, Transportation Research Institute, University of Michigan
Researchers	Dr. Randa Radwan, Former Director of Highway Safety Research Center at the University of North Carolina
Researchers	Dr. Stewart Wang, International Center for Automotive Medicine, University of Michigan
Researchers	Dr. Warren N. Hardy, Center for Injury Biomechanics, Virginia Tech and Dr. Ashley Weaver, Center for Injury Biomechanics, Wake Forest University School of Medicine
Researchers	Drs. Anna Carlsson (Chalmers Industriteknik), Rikard Fredriksson (The Swedish Transport Administration), Astrid Linder (The Swedish National Road and Transport Research Institute), Pernilla Bremer (The Swedish Transport Agency), Mats Svensson (Chalmers), Anders Kullgren (Folksam) and Magnus Granström (SAFER). All organizations are partners in SAFER Vehicle and Traffic Safety Centre at Chalmers University
Auto industry associations	Alliance for Automotive Innovation
Auto industry associations	Automotive Safety Council
Safety organizations	Advocates for Highway and Auto Safety
Safety organizations	Center for Auto Safety
Safety organizations	Consumer Reports
Safety organizations	Insurance Institute for Highway Safety
Safety organizations	National Safety Council
Safety organizations	Verity Now
Retired vehicle safety engineers	Dr. Kennerly Digges
Retired vehicle safety engineers	Dr. Priya Prasad
Vehicle Manufacturers	General Motors
Vehicle Manufacturers	Ford
Vehicle Manufacturers	American Honda Motor Co., Inc.

Appendix I: List of Industry Stakeholders Interviewed

Category	Category information
Vehicle Manufacturers	Hyundai America Technical Center, Inc.
Vehicle Manufacturers	Mercedes-Benz Research & Development North America, Inc.
Vehicle Manufacturers	Toyota Motor North America, Inc.
Dummy manufacturer	Humanetics
Modeling company	Elemance, LLC[a]

Source: GAO. | GAO-22-105595

[a]Representatives of Elemance, LLC, Drs. Joel Stitzel and Scott Gayzik, are affiliated with the Wake Forest University School of Medicine.

Appendix II: Child-Size Dummies Used in Testing for Federal Motor Vehicle Safety Standards Compliance and New Car Assessment Program

There are a variety of child-size crash test dummies used to ensure child restraint systems—such as rear-facing and forward-facing car seats and booster seats—meet the applicable Federal Motor Vehicle Safety Standards (FMVSS) and inform New Car Assessment Program (NCAP) (see fig. 11).[1] Manufacturers of add-on child restraint systems, rather than vehicle manufacturers, are required to certify that their child restraints comply with applicable FMVSS. Vehicle manufacturers must certify compliance of built-in child restraints.[2] NHTSA has noted that both add-on child restraint system manufacturers and vehicle manufacturers generally conduct the tests with dummies specified in the FMVSS as the basis for their certification, even though they are not required to do so. NHTSA explained that this is because manufacturers know that NHTSA will conduct FMVSS tests with child dummies to verify their compliance.[3]

[1]The FMVSS are the federal minimum safety standards for new motor vehicles and motor vehicle equipment and are located in 49 C.F.R. Part 571. These standards specify performance requirements that the vehicles and equipment must meet before they may be sold in the U.S. *See* 49 U.S.C. § 30112. FMVSS No. 213 and FMVSS No. 213a specify these requirements for child restraint systems in front-impact and side-impact dynamic sled tests, respectively. Both standards require child restraint systems to be designed in a way that limits how much the head and chest of the dummy move during these tests to reduce the possibility of head injury from contact with vehicle interior surfaces and ejection, and maintains system integrity (i.e., not fracture or separate in such a way as to harm a child).

[2]*See* 49 U.S.C. § 30115.

[3]Federal Motor Vehicle Safety Standards; Child Restraint Systems, Child Restraint Systems-Side Impact Protection, Incorporation by Reference, 87 Fed. Reg. 39234, 39291 n.225 (June 30, 2022).

Figure 11: Child-Size Crash Test Dummies Used for Federal Motor Vehicle Safety Standards (FMVSS) and New Car Assessment Program (NCAP)

	Hybrid III 10-year-old child	Hybrid III 6-year-old child	Hybrid III 6-year-old weighted child	Hybrid III 3-year-old child	Q3s 3-year-old child	CRABI 12-month-old infant	CAMI Newborn Infant
Height (feet)	4’3”	3’11”	3’11”	3’1”	3’3”	2’5”	1’8”
Weight (pounds)	78	52	62	36	32	22	7.6
Used in	• FMVSS frontal sled test for child restraint systems	• FMVSS frontal sled test for child restraint systems • FMVSS front air bag risk assessment • NCAP side air bag risk assessment	• FMVSS frontal sled test for child restraint systems	• FMVSS frontal sled test for child restraint systems • FMVSS front air bag risk assessment • NCAP side air bag risk assessment	• FMVSS side sled test for child restraint systems	• FMVSS frontal sled test for child restraint systems • FMVSS side sled test for child restraint systems, assessing containment • FMVSS front air bag risk assessment	• FMVSS frontal sled test for child restraint systems

FMVSS: Federal Motor Vehicle Safety Standards NCAP: New Car Assessment Program

Source: National Highway Traffic Safety Administration. | GAO-23-105595

NHTSA is also in the process of developing a technologically advanced child-size dummy, the Large Omnidirectional Child dummy, representing a 10-year-old child at 4’3” and 76 pounds (see fig. 12). According to NHTSA, this new child dummy is similar in stature to the Hybrid III 10-year-old child dummy, but more realistically represents a child occupant.

For example, the new dummy contains sensors in the abdomen and has a more flexible spine and neck, among other differences. According to NHTSA documents, this dummy's instrumentation can more comprehensively assess the risk of injuries that are typical for improperly restrained children.

Figure 12: Large Omnidirectional Child Crash Test Dummy

Source: Center for Child Injury Prevention Studies, Children's Hospital of Philadelphia Research Institute, and The Ohio State University. | GAO-23-105595

Currently used child dummies differ from adult dummies in multiple ways:

- Child dummies are used to assess the protection provided by child car seats and restraint systems, and not the vehicle itself.
- Child dummies are used in sled tests that replicate crash forces instead of full-scale vehicle crashes.
- Child dummies, other than the newborn infant, are equipped with some instrumentation to measure crash forces, but they generally collect less information than adult dummies.

- Child dummies were scaled down from adult dummies due to lack of data on how children's bodies respond to crash forces.[4]

Child Dummies in the FMVSS

The FMVSS requires that add-on child restraint systems are tested using child dummies in a front-impact sled test that replicates an approximately 30-mile-per-hour crash (see fig. 13).[5]

[4]The Large Omnidirectional Child dummy is more representative of a 10-year old child than a dummy scaled down from an adult dummy.

[5]FMVSS No. 213. A sled test is used to evaluate the safety of child restraint systems without the cost of a full-scale crash test using a vehicle.

Figure 13: A 3-Year Old Child Crash Test Dummy in a Frontal Sled Test

Source: National Highway Traffic Safety Administration. | GAO-23-105595

In June 2022, NHTSA issued a final rule establishing side impact performance requirements for child restraint systems designed for children up to 40 pounds or for children up to 3 feet and 7 inches tall.[6] This test was designed to replicate a vehicle moving at 30 miles per hour striking the side of another vehicle moving at 15 miles per hour (see fig. 14). NHTSA stated that larger children will benefit from the improvements

[6]These performance requirements are located in FMVSS No. 213a. NHTSA issued the final rule to fulfill a statutory mandate in the Moving Ahead for Progress in the 21st Century Act, which required NHTSA to amend FMVSS No. 213 to improve the side-impact crash protection of children seated in child restraint systems. Pub. L. No. 112-141, § 31501(a), 126 Stat. 405, 773-774 (2012); Federal Motor Vehicle Safety Standards; Child Restraint Systems, Child Restraint Systems-Side Impact Protection, Incorporation by Reference, 87 Fed. Reg. 39234 (June 30, 2022).

(such as better padding, added padding, or other added safety measures) that will be included in restraint systems to meet the new standard. According to NHTSA, this new test will ensure that child restraint systems prevent head contact with an intruding vehicle door or child restraint structure, thereby reducing crash forces to the child's head and chest.

Figure 14: A Child Crash Test Dummy in New Side-Impact Sled Test

Child

Source: National Highway Traffic Safety Administration. | GAO-23-105595

Child Dummies in NCAP Crash Tests

For NCAP, two of the child dummies (3 year-old and 6 year-old) are used in side airbag risk assessment tests, which check to ensure vehicle side

airbags do not deploy in a manner that would be harmful to an out-of-position child.[7]

[7]According to NHTSA officials, vehicle manufacturers self-report the results of side airbag risk assessment tests with child dummies. If a manufacturer submits information that a vehicle model meets the out-of-position test requirements, NHTSA notes that on the website for each vehicle make and model under the “all vehicle safety features.” NHTSA spot checks models to verify information submitted by manufacturers. The side airbag test results do not affect the NCAP star rating system.

Appendix III: Comments from the Department of Transportation

U.S. Department of Transportation
Office of the Secretary of Transportation

Assistant Secretary for Administration

1200 New Jersey Avenue, SE
Washington, DC 20590

February 21, 2023

Elizabeth Repko
Director, Physical Infrastructure Issues
U.S. Government Accountability Office (GAO)
441 G Street, NW
Washington DC 20548

Dear Ms. Repko:

The mission of the National Highway Traffic Safety Administration (NHTSA) is to save lives, prevent injuries, and reduce the economic impacts of crashes occurring on the Nation's roadways. NHTSA's top priorities are to improve safety through Federal safety standards and safety ratings. NHTSA is committed to ensuring its safety assessments provide the best information for improving occupant protection in vehicle crashes.

NHTSA concurs with the recommendation to develop and communicate a plan to address limitations in the information dummies provide related to the greater risks certain demographic groups face in vehicle crashes. The plan would explain how efforts will respond to risks, set milestones for activities, and establish mechanisms to communicate decisions and progress. We will provide a detailed response to this recommendation within 180 days of the final report's issuance.

NHTSA appreciates the opportunity to respond to the GAO draft report. Please contact Gary Middleton, Director of Audit Relations and Program Improvement, at (202) 366-6512 with any questions or if GAO would like to obtain additional information.

Sincerely,

Philip A. McNamara
Assistant Secretary for Administration

Accessible Text for Appendix III: Comments from the Department of Transportation

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Sincerely,

Philip A. McNamara
Assistant Secretary for Administration

Appendix IV: GAO Contact and Staff Acknowledgments

GAO Contact

Elizabeth Repko at (202) 512-2834 or repkoe@gao.gov.

Staff Acknowledgments

In addition to the contact above, Sara Vermillion (Assistant Director); Matthew Rosenberg (Analyst-in-Charge); Amy Abramowitz; Michelle Everett; Amy Higgins; Joshua Ormond; Mary-Catherine P. Overcash; Kelly Rubin; Pamela Snedden; Carlin Van Holmes; Noah Vehafric; and Laurel Voloder made key contributions to this report.

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