IIHS
Insurance Institute for Highway Safety

Moderate Overlap Frontal Crashworthiness Evaluation

Guidelines for Rating Restraints and Dummy Kinematics

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The injury measures obtained from a 50th percentile male Hybrid III dummy seated in a standard driver's position are good indicators of the injury risk for a person of about the same size in the same seating position. However, good injury results for the standard dummy and seating position are not sufficient by themselves to indicate low injury risk for drivers of different sizes and/or seating positions in the same crash. For example, the dummy's head moving outside the occupant compartment and/or the steering column moving excessively during the crash indicate the potential for injuries that are not necessarily captured by recorded injury measures on a single dummy.

To provide some assessment of the potential injury risk for drivers of other sizes and/or seating positions, the Institute reviews the kinematics of the 50th percentile dummy during the offset crash, together with the performance of the restraint system (seat belts, airbag, steering column, seat and seat riser, and door). The actual evaluation is based on analysis of dummy movement on the high-speed film plus measurements of steering column movement.

The basic characteristics of good occupant restraint/dummy kinematics performance are:

- dummy should move straight forward into a fully deployed airbag and then return directly to the seat during rebound;
- head and body should stay behind and within the extended perimeter of the airbag;
- head should not approach hard surfaces of the vehicle interior;
- rearward and upward movement of the steering column should be minimal; and
- lap belts should have stable anchorages that allow only minimal lengthening or spool-out even when force-limting devices are used.

Such exemplary performance has been observed in a number of Institute offset crash tests (e.g., 1995 and 1998 Honda Accords, 1997 BMW 5 series, 1998 Toyota Sienna, and 2000 Chevrolet Impala).

Minor deviations from these ideal characteristics can still result in a good rating. For example, contact with the B-pillar, roof rail between the A- and B-pillars, or the top of the A-pillar during rebound from the airbag generally results in no downgrading of occupant restraints and kinematics, as long as that contact is due principally to the rotation of the vehicle on rebound from the barrier rather than to excessive movement of the dummy (e.g., 1995 Ford Taurus, 1997 Toyota Camry, and 1997 Ford Escort). Also, if the dummy's head bottoms out the airbag and strikes the stiffer steering wheel/hub underneath, there is generally no downgrading of occupant restraints and kinematics. (Note that pillar, roof rail, or steering wheel contact could affect the head injury rating if the associated head acceleration is >70 g; see dummy injury assessment procedures for more detail. Also, multiple head contacts of >70 g will affect the rating of restraints and kinematics; see next page.)

Other departures from these ideal characteristics can be dramatic. The head may move forward and downward toward the lower part of the A-pillar as the dummy loads the left side of the airbag and begins to slide by (e.g., 1995 Mitsubishi Galant), or the dummy may flail through the side window and strike its head on stiff structure two or more times (e.g., 1995 Chevrolet Cavalier). Such observations indicate significant injury risk in this kind of crash, even if the

dummy in the particular test is "lucky" and records only low or moderate injury measures. These movements usually are associated with instability of the driver seat and severe deformation of the door structure so that it no longer prevents the dummy from sliding left as the vehicle rebounds and rotates. Severe intrusion of the steering column is often seen in vehicles with these dummy kinematics, as well. Any of these kinematic observations results in a poor rating for occupant restraints and dummy kinematics.

In addition, certain observations about the restraint system can lead to a poor rating, regardless of dummy kinematics:

- vehicle door opening during the crash (e.g., 1996 Ford Explorer, 1997 Mercedes E-class);
- failure of the seat attachment mechanism when the lap belt is anchored to the seat (e.g., 1995 Nissan Maxima);
- excessive lap belt slack (>150 mm) introduced through webbing tear stitching (e.g., 1996 Toyota Previa); or
- failure of an airbag to deploy in time to prevent the head from contacting the steering wheel directly (e.g., 1999 Chrysler LHS, 2001 Ford F-150).

In between these clear extremes of dummy kinematics and restraint performance, vehicles are rated either acceptable or marginal. Observations that typically result in an acceptable rating, if there are no other restraints or kinematic concerns, include:

- late deploying airbag — although not so late that the dummy's head strikes the steering wheel directly. For example, the airbag deploys late enough that its initial contact with the dummy's head is on the front half of the airbag (i.e., the portion of the airbag facing the steering wheel), as the dummy's head approaches the steering wheel;
- movement of *most* of the dummy's head through the original plane of the vehicle side window;
- two or more distinct head contacts with stiff structure that each generate more than 70 g of maximum acceleration (e.g., contacts with the steering wheel *and* B-pillar)
- instability of the seat due to floorpan or seat riser deformation. This is typically characterized by 6 cm or more of relative vertical motion between any of the seat attachment points to the floor or other distortions that result in the seatback moving outboard toward or against the B-pillar;
- excessive rearward or upward movement (≥100 mm) of the steering column;
- moderately excessive (100-150 mm) uncontrolled lengthening of the lap belt;
- burning or melting of dummy body parts or clothing due to expulsion of hot gases from deflating airbags during impact; and
- deployment of frontal airbags in separate bumper tests conducted by the Institute on the same vehicle year, make, and model at impact speeds below 15 km/h (9 mi/h).

A marginal rating would occur if:

- dummy movement were considerably less controlled (e.g., the head and shoulders pass through the original plane of the side window or there is sufficient rotation of the upper torso for the head to face upward or nearly upward on rebound from the airbag), regardless of contact with stiff structure; or
- otherwise acceptable dummy kinematics were *combined* with late airbag deployment without steering wheel contact, multiple hard head contacts, excessive seat instability, excessive steering column movement, moderately excessive lap belt lengthening, burning

or melting of dummy body parts or clothing, or frontal airbag deployment in bumper tests.

Similarly, a poor rating would occur if:

- otherwise marginal dummy kinematics were *combined* with late airbag deployment without steering wheel contact, excessive seat instability, excessive steering column movement, moderately excessive lap belt lengthening, burning or melting of dummy body parts or clothing, or frontal airbag deployment in bumper tests.

Figures 1-7 provide examples of the application of these guidelines.

Figure 1. An example of good performance, the 2000 Chevrolet Impala (CF99014). Dummy movement was well controlled. After the dummy moved forward into the airbag, it rebounded into the seat without its head coming close to any stiff structure that could cause injury; the dummy's head contacted only the head restraint.

Figure 2. Another example of good performance, the 1998 Honda Accord (CF98001). As in the 2000 Chevrolet Impala, dummy movement was well controlled. After moving forward into the airbag, the dummy rebounded into the seat without its head coming close to any stiff structure that could cause injury.

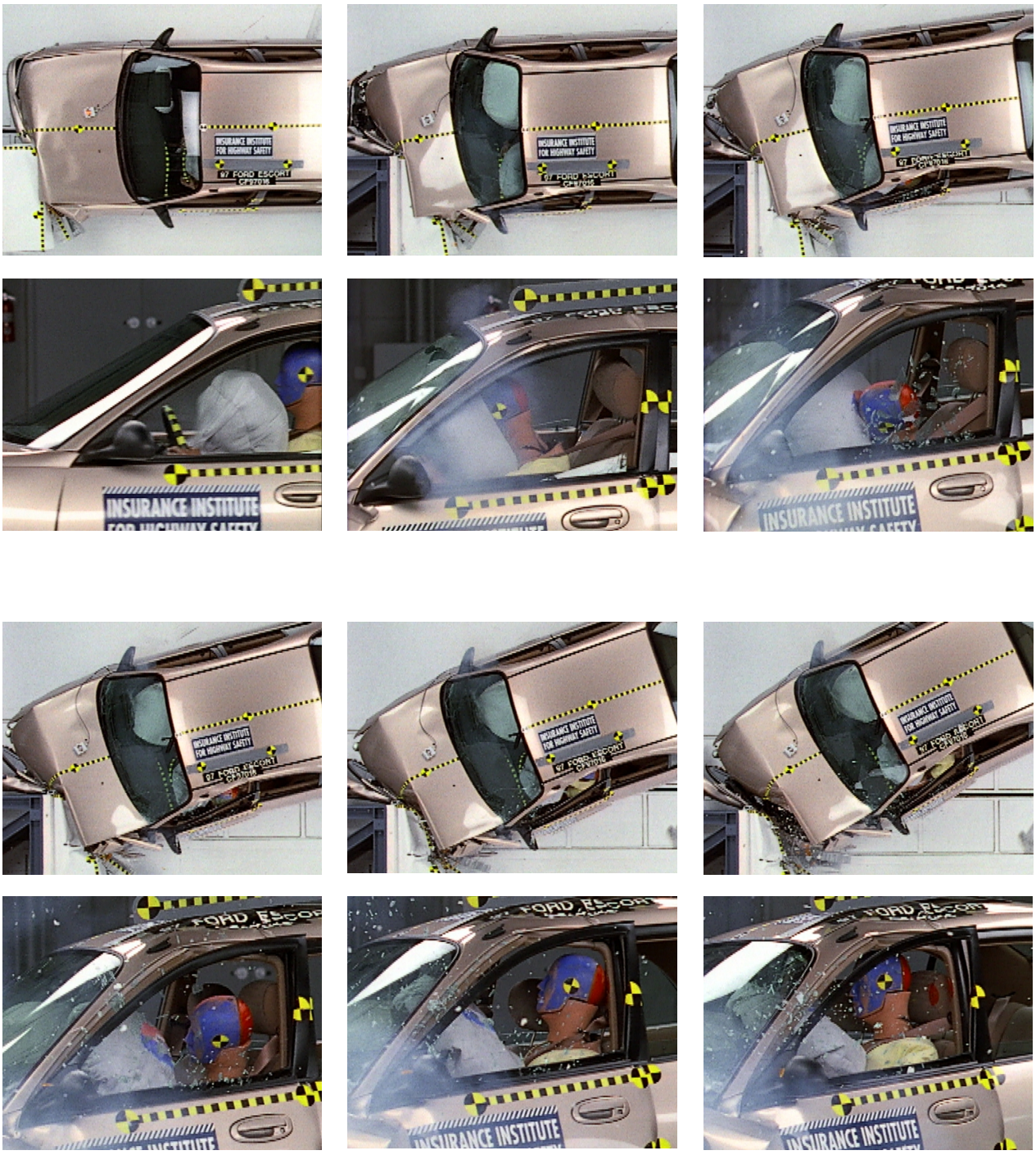

Figure 3. Another example of good performance, the 1997 Ford Escort (CF97016). Dummy movement was well controlled. Although the dummy's head did contact the B-pillar during rebound (as the vehicle rotated), the head remained within the occupant compartment throughout the crash.

Figure 4. An example of acceptable performance, the 1999 Mazda Protege (CF99005). After the dummy moved forward into the airbag, it moved toward the driver door,. The dummy's head moved through the plane of the side window during rebound, lowering the rating to acceptable.

Figure 5. An example of marginal performance, the 2000 Isuzu Rodeo (CF00014). During rebound from the airbag, the dummy moved toward the driver door. Its head leaned through the open side window and approached but did not contact the window sill. In combination with sufficient rotation of the upper torso for the head to face nearly upward, this motion lowered the rating to marginal.

Figure 6. An example of poor performance, the 1995 Mitsubishi Galant (CF95008). The dummy rotated around the left side of the airbag. Its left shoulder hit a sharp edge of the buckling window frame, which could cause lacerations, and its head hit the window frame.

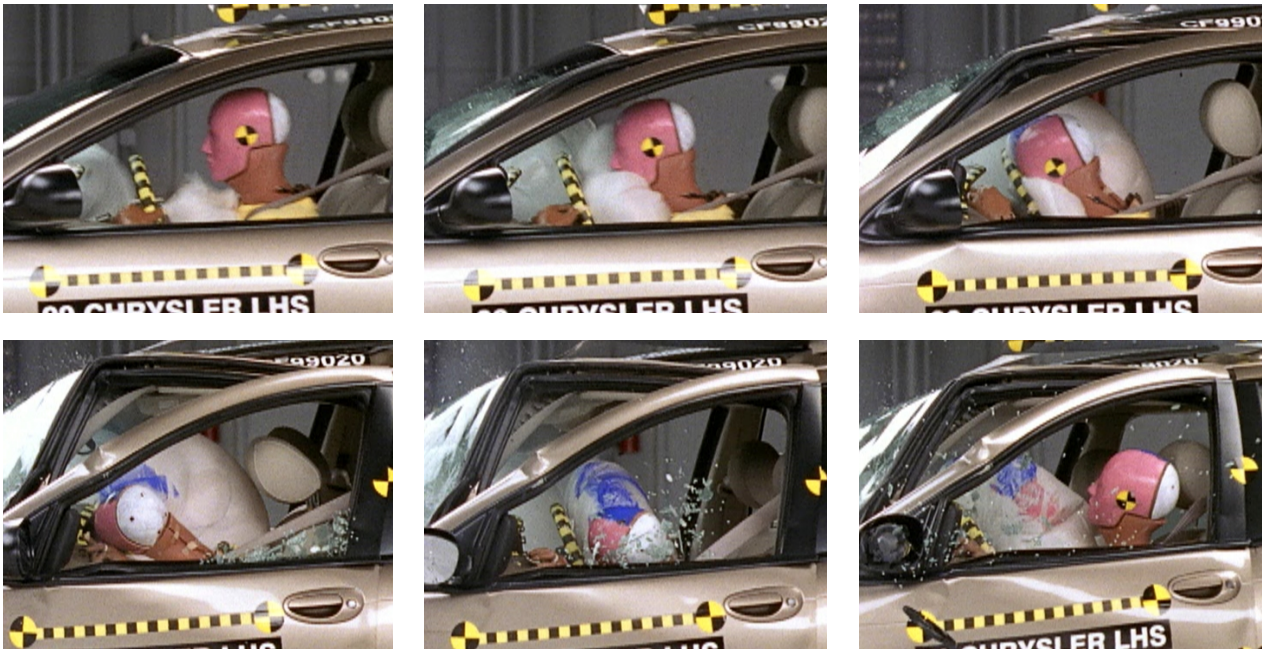

Figure 7. Another example of poor performance, the 1999 Chrysler LHS (CF99020). The airbag deployed too late, allowing the dummy's head hit the steering wheel directly.