An Investigation of Local Accelerator Pedal Geometry Effects on Ankle Motion

Stacey Webb, Junior Noss, Jason Forman

University of Virginia
School of Engineering & Applied Science

INTRODUCTION

- Frontal Collision Injuries: lower extremity injuries are a frequent outcome of frontal vehicle crashes; resulting in long-term disability and reduced mobility
- Specific injury modes have been well-documented, currently little literature examines local footwell geometries on the impact of gross kinematic motion of the foot and ankle
- Despite well-documented injury modes, no existing literature directly examines the relationship between local accelerator pedal geometry and gross ankle kinematics across a diverse fleet of production vehicles

OBJECTIVE

The study aims to understand how vehicle and collision attributes such as pedal geometry and independent brake pedal movement influence ankle kinematics using publicly available full-vehicle crash tests.

METHODS

- Testing Data Source: reports and highspeed videos from the Insurance Institute for Highway Safety's TechData for frontal and side impact tests
  - 157 total crash tests
  - Testing range: January 2023 – July 2025
- Car physical features, origins, occupant ankle response, and pedal box displacement in testing outcomes
  - Physical features: weight, accelerator pedal shape, vehicle classification
  - Origin: make, model, year, manufacturer, and manufacturing location
  - Ankle response: inversion/eversion
  - Pedal box: brake pedal displacement; left, center, right toe pan displacement
- Duplicate tests were compared to each other for repeatability, but excluded from other analysis

RESULTS

Overall Results

Ankle Motion
- 54% Eversion (85)
- 29% Inversion (46)
- 17% Inconclusive (26)

Pedal Motion
- 29% Visible Movement (38)
- 61% No Visible Movement (81)
- 9% Possible Movement (12)
- 26 Tests Not Visible

Vehicle Type

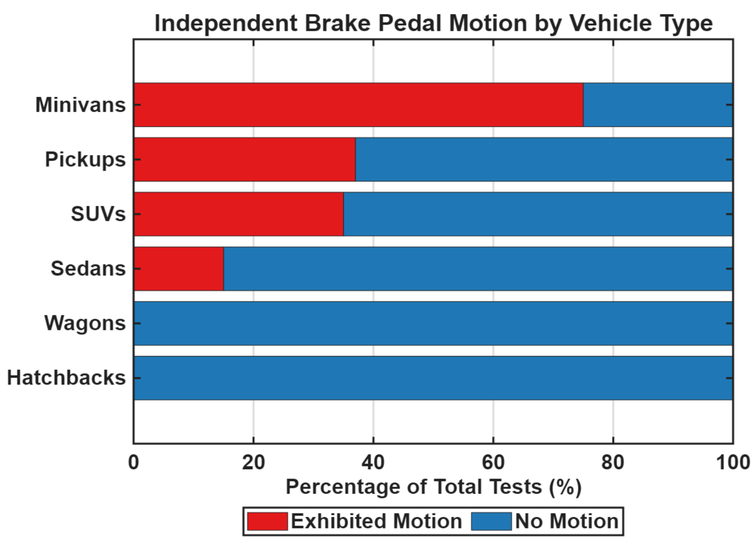

Figure 1. Crash testing brake pedal response by vehicle classifications. Minivans see the highest rate of brake pedal movement at 75%, while hatchbacks and wagons both have no tests with brake pedal motion

Manufacturer

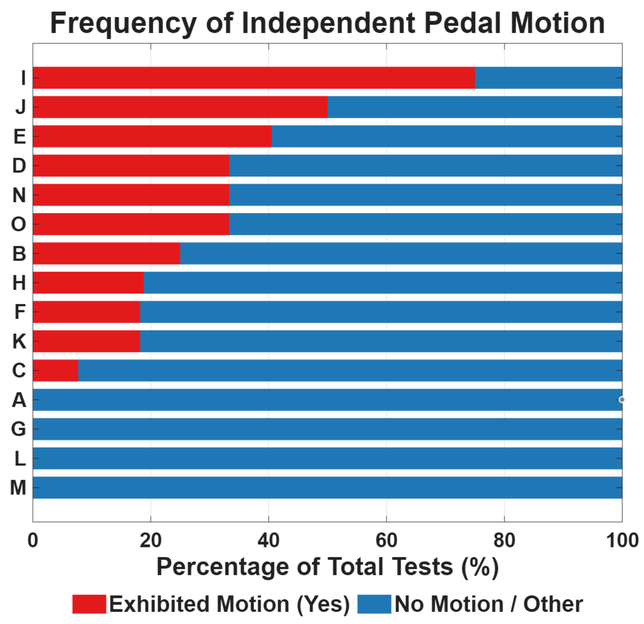

Figure 2. Independent Brake Pedal Motion by Manufacturer. Manufacturer I has the highest rate of brake pedal motion at 75%, while A, G, L, and M each have 0% with definitive motion.

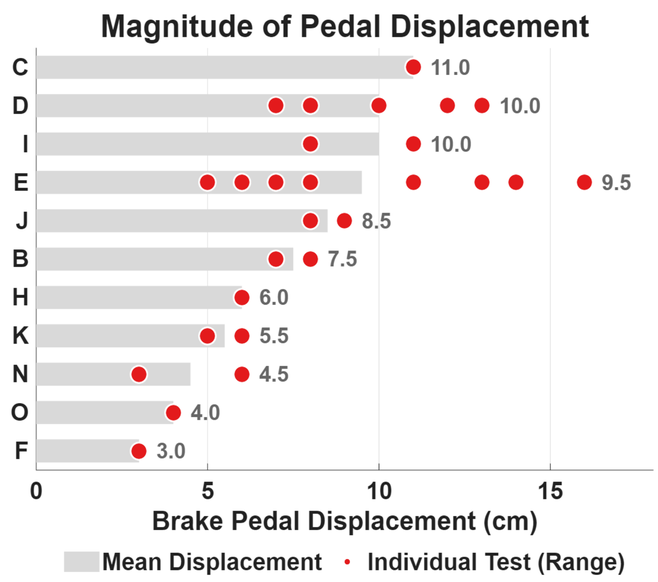

Figure 3. Magnitude of Pedal Displacement by Vehicle Manufacturer. C has the highest mean displacement of 11cm, while the highest individual displacement is a B vehicle with a 35 cm displacement.

Pedal Geometry

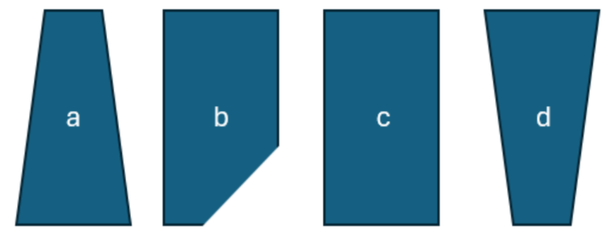

Figure 4. Simplified Pedal Geometries: Bottom thick (a), diamond (b), rectangle(c), and top thick (d) accelerator pedal shapes

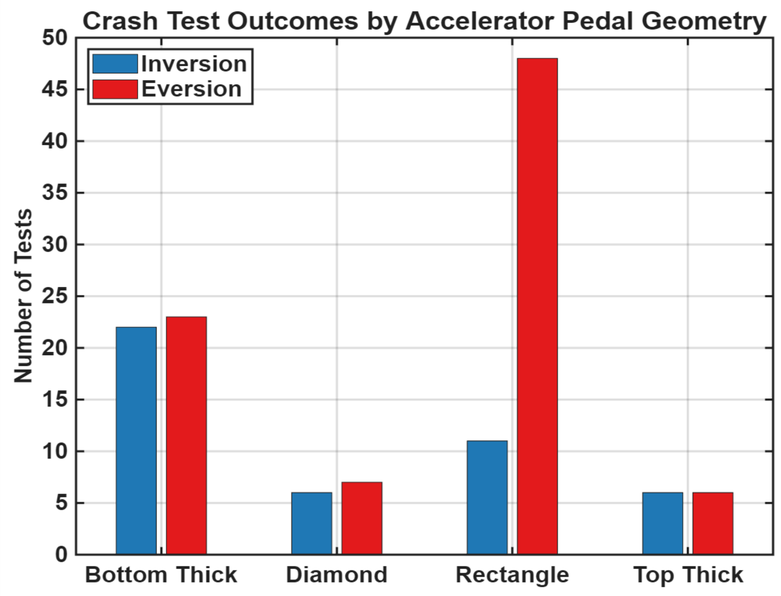

Figure 5. Ankle Kinematics by Simplified Accelerator Geometry. Bottom thick, diamond, and top thick pedal geometries all have similar rates for ankle inversion and eversion. Rectangle accelerator pedal shapes have disproportionately high eversion rates.

SUMMARY

Of 157 IIHS crash tests analyzed across 15 manufacturers, ankle eversion was the dominant response (54%). Rectangle-shaped accelerator pedals showed a disproportionately high rate of eversion compared to other pedal geometries. Independent brake pedal motion was better predicted by manufacturer than vehicle type, with manufacturer I (75%) showing the highest rate. These results suggest that pedal geometry and braking system design choices may have unrecognized consequences for occupant ankle injury in frontal crashes.

FUTURE WORK

- Expand dataset to include crash tests outside the Jan. 2023–July 2025 window and additional vehicle classes
- Collect quantitative pedal geometry measurements (height, angle, surface area) to enable continuous rather than categorical analysis
- Investigate the mechanical mechanism linking rectangle pedal geometry to eversion through controlled lab testing with ATDs or cadaveric specimens
- Cross-reference findings with real-world injury databases (e.g., CIREN, NASS-CDS) to connect crash test kinematics to clinical outcomes

REFERENCES

1. [1] Insurance Institute for Highway Safety, "TechData: Frontal and side impact crash tests (Jan. 2023–Jul. 2025)," IIHS.org. [Online]. Available: https://www.iihs.org/.

Center for Applied Biomechanics

Stacey Webb
bat8ym@virginia.edu