

# SEATBELT FIT AND SAFETY PERCEPTIONS FOR PREGNANT AUTOMOBILE OCCUPANTS

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Jason Forman, Keri-Anne Lue, Corina Espelien, Pavel Chernyavskiy

September 2026



# UVA Center for Applied Biomechanics

- ▶ UVA Dept. of Mechanical and Aerospace Engineering
- ▶ 35+ years in injury biomechanics: automobile safety, defense, sports – experimental, modeling, epidemiology
  - Multi-disciplinary group of 50+ people in a 30,000 ft<sup>2</sup> facility
    - 9 faculty (6 School of Engineering, 3 School of Medicine)
    - 4 research scientists and post-docs (PhD)
    - 13 technicians and engineers
    - 30+ graduate students, interns



# Automobile Safety During Pregnancy

## ► Unique challenges:

- Protection of both the mother and the fetus
- Safety perceptions
- Anthropometry
- Belt use & fit
- Unique injury types



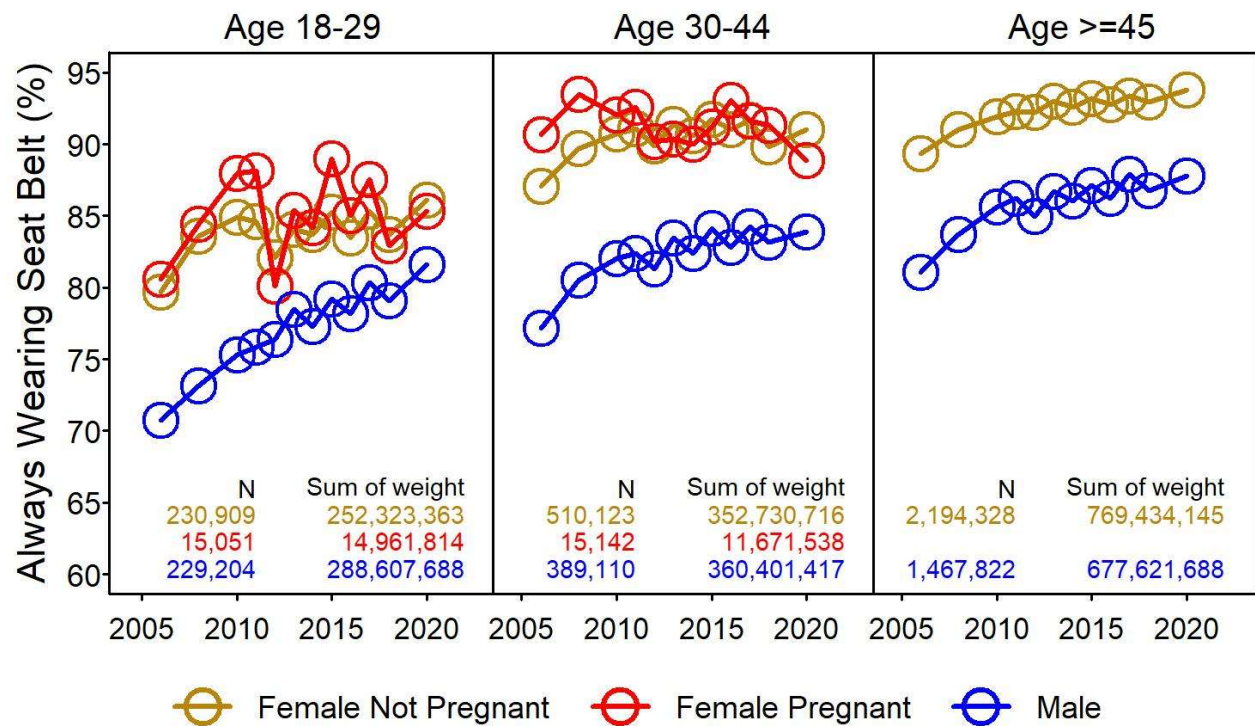
# Belt Use Rates for Pregnant Women

Recent UVA analysis using Behavioral Risk Factor Surveillance Systems (BRFSS)

- Pregnant women report wearing their belts at similar rates to their age group

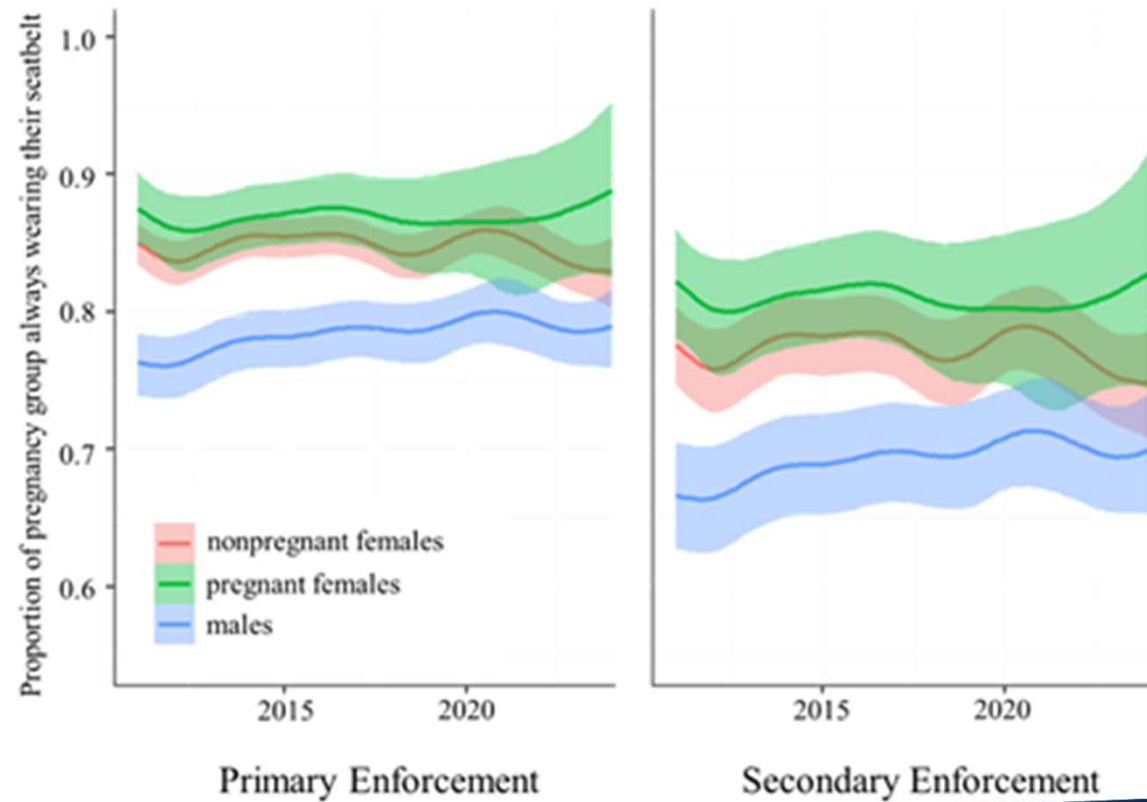


Challenge: many pregnant women in younger age group, where belt use is lower



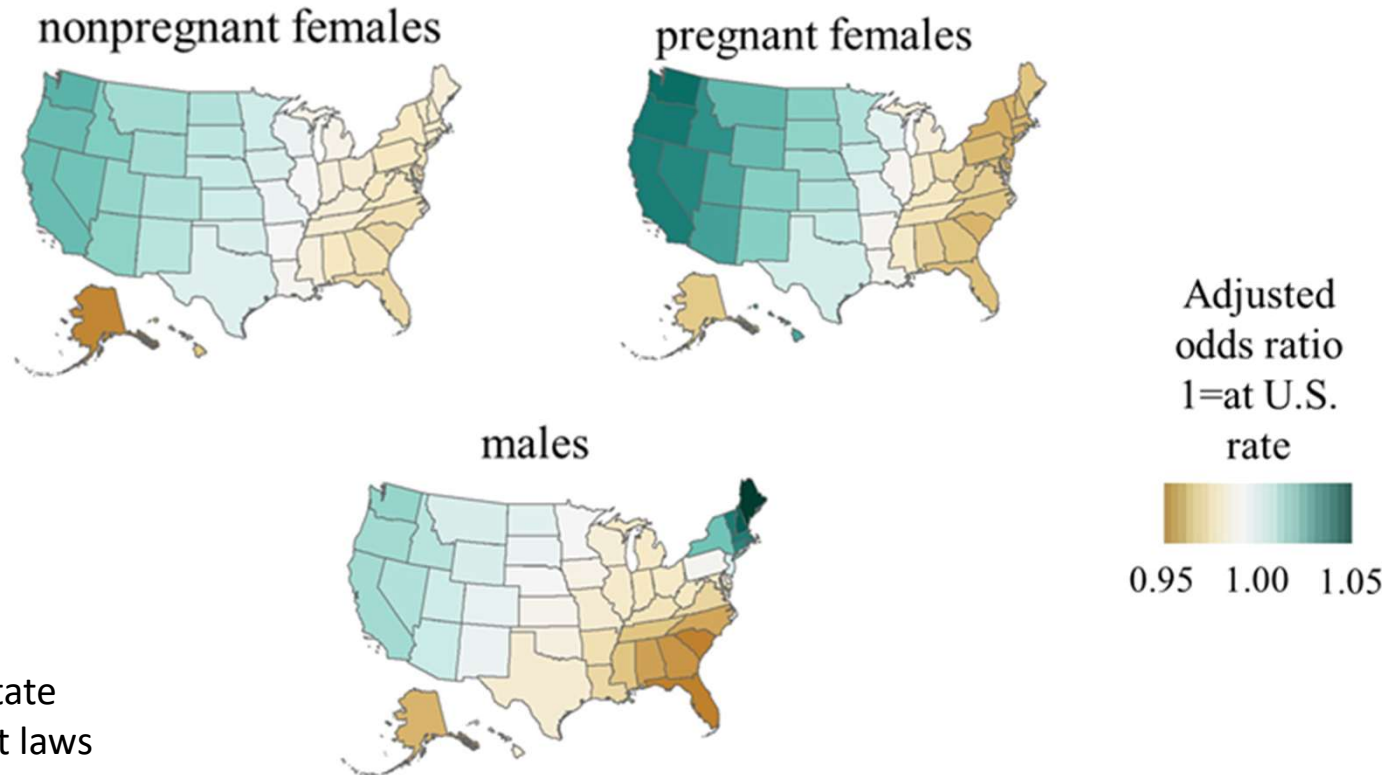
Published: JAMA Network Open 2024 (Espelien et al.)

# TEMPORAL TRENDS IN SEATBELT USE



BRFSS 2011-2024  
Averaged over age

# GEOGRAPHIC TRENDS IN SEATBELT USE



BRFSS 2011-2024

Adjusted for age & state  
primary enforcement laws

## SUMMARY

- As observed before, pregnant females tend to wear their seatbelt at or above the rate of non-pregnant females
  - No systematic hesitancy for wearing seatbelt.
  - Skew young, and are prone to same age-related depression of seatbelt use as the rest of the population.
  - Also prone to same trends with enforcement as the rest of the population.
- Geographic trends
  - Females: East-West difference in belt use
  - Males: Southeast & Mid-West (lower rates) vs. North-East & West Coast (higher rates)

# OPPORTUNITIES FOR EDUCATION & INFORMATION

## IF YOU'RE PREGNANT SEAT BELT RECOMMENDATIONS FOR DRIVERS AND PASSENGERS

### I'M PREGNANT. SHOULD I WEAR A SEAT BELT?

**YES**—doctors recommend it. Buckling up through all stages of your pregnancy is the **single most effective** action you can take to protect yourself and your unborn child in a crash.

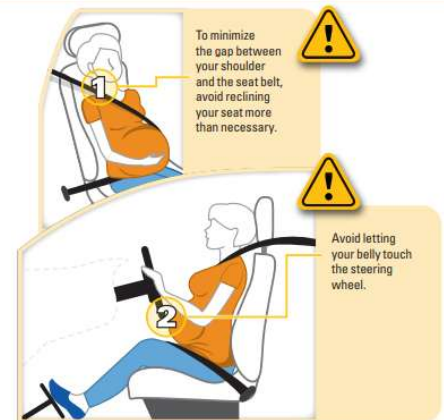
**NEVER**  
drive or ride in a car  
without **buckling up** first!

### WHAT'S THE RIGHT WAY TO WEAR MY SEAT BELT?



## NHTSA Pamphlet

### SHOULD I ADJUST MY SEAT?



\* If you need additional room, consider adjusting the steering wheel or having someone else drive, if possible.  
\*\* If you're a passenger, move your seat back as far as possible.

Project Goal: Expand the availability of pregnant occupant research data by conducting a volunteer study in a naturalistic environment

Objectives



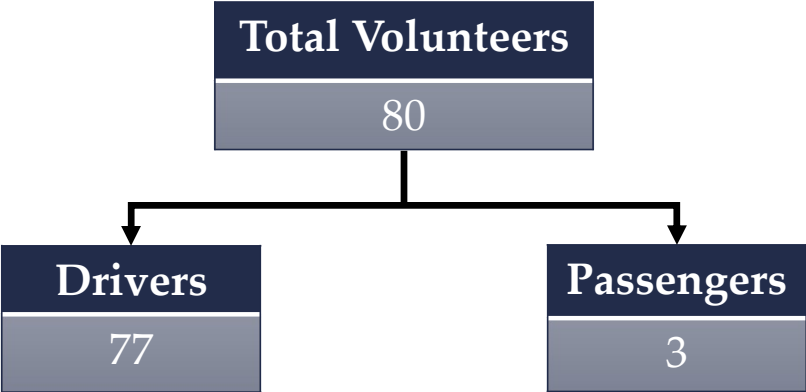
Identify variations in belt fit across different gestational ages



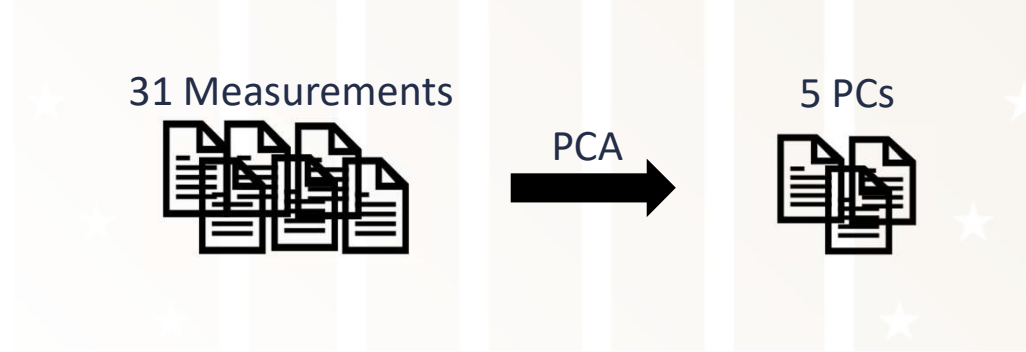
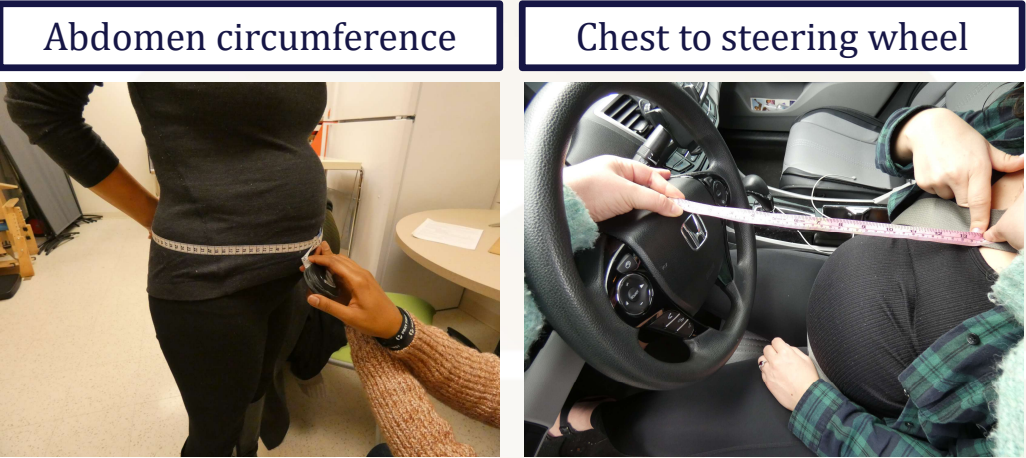
Assess comfort in comfortable and rear-adjusted seating positions



Understand state of knowledge of seat belt safety during pregnancy



| Seating Position | Anthropometric measurements | In-vehicle Measurements |
|------------------|-----------------------------|-------------------------|
| Comfortable      | 8                           | 23                      |



# Example Observations

Variations in seat belt fit within gestational age: Case comparison



27 weeks



24 weeks

# Example Observations

Variations in seat belt fit within gestational age: Case comparison



17 weeks



16 weeks

**PC1: Body Size (25.2% variance explained)**

Strongest Loadings (in order)

Positive

- Seated abdomen depth
- Abdomen circumference
- Hip circumference
- Weight

Negative

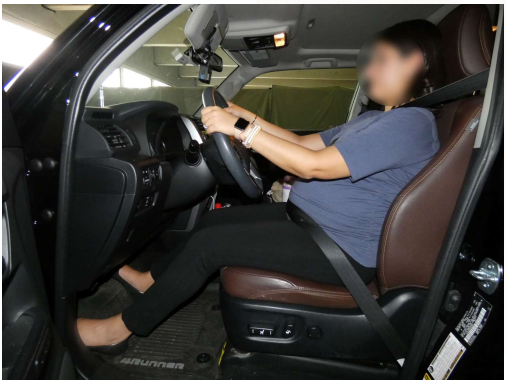
- Dist. from abdomen to steering wheel
- Shoulder belt take-off angle

Low



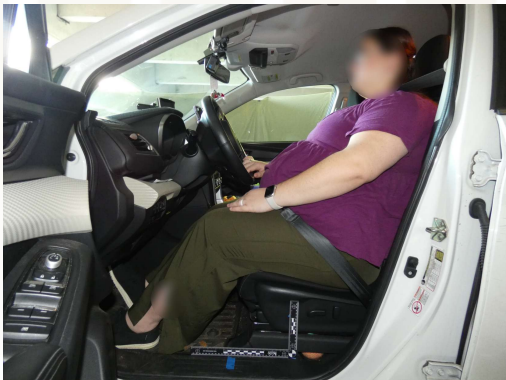
Volunteer 17

Average



Volunteer 31

High



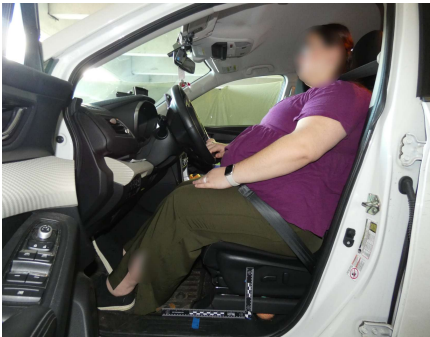
Volunteer 38

PC1: Body Size  
25.2% Variance Explained

Low

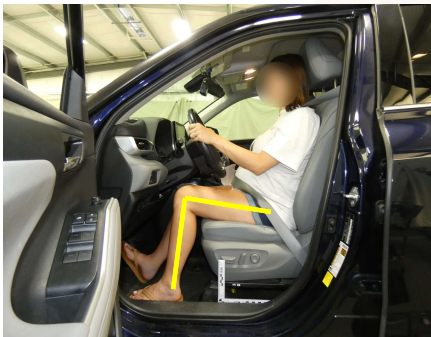


High

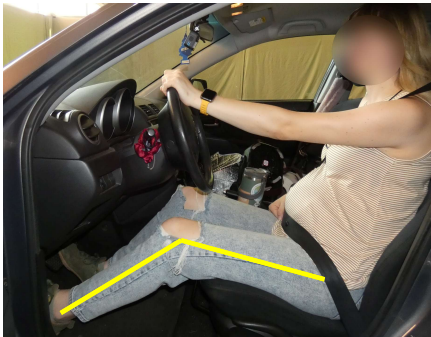


PC2: Lower Limb Extension  
10.8% Variance Explained

Low

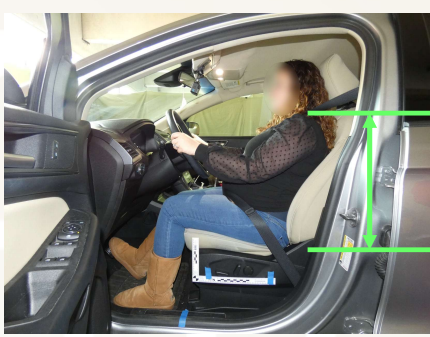


High

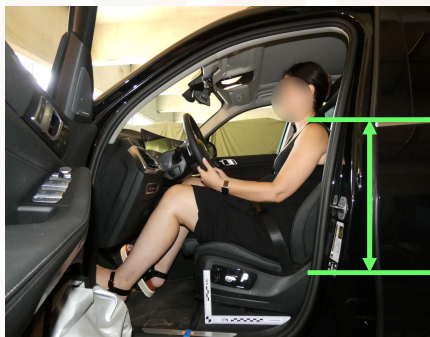


PC3: Seated Torso Height  
9.8% Variance Explained

Low



High



PC4: Relative Limb Angle  
6.9% Variance Explained

Low



High



PC5: D-ring Position  
6.1% Variance Explained

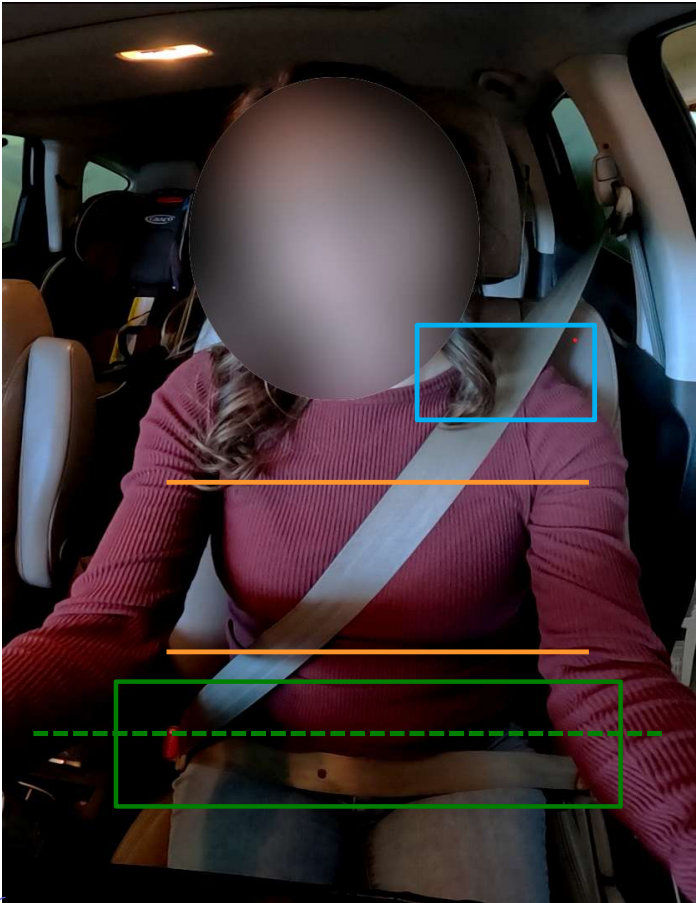
Low



High



# What is the recommended way for pregnant occupants to wear a seat belt?



## Clavicle

- Resting on the clavicle
- Between neck and edge of shoulder

## Sternum

- Between the breasts
- Not too high/low on the sternum

## Lap

- Below the belly button
- Under the bump
- Across the hips

# How did we code proper belt fit?

**IF YOU'RE PREGNANT SEAT BELT RECOMMENDATIONS FOR DRIVERS AND PASSENGERS**

**I'M PREGNANT. SHOULD I WEAR A SEAT BELT?**

**YES**  
—Doctors recommend it. Buckling up through all stages of your pregnancy is the **single most effective** action you can take to protect yourself and your unborn child in a crash.

**NEVER**  
drive or ride in a car without **buckling up first!**

**WHAT'S THE RIGHT WAY TO WEAR MY SEAT BELT?**

**RIGHT**  
**SHOULDER BELT**  
Always wear your seat belt (don't take it off your shoulder).  
Secure your chest (between your breasts).  
Do not let the belt slip off your back.  
**LAP BELT**  
Secure it below your belly button. It should snugly secure your hips and pelvic bones.

**WRONG**  
**SHOULDER BELT NEVER**  
Do not wear your seat belt under your arm or behind your back.  
**LAP BELT NEVER**  
Do not wear it so it sits top of your belly.

**SHOULD I ADJUST MY SEAT?**

**YES**  
**ADJUST SEAT**  
comfortable, upright position.  
Keep as much distance as possible between your belly and the steering wheel.  
Comfortably reach the steering wheel and pedals.  
\* If you need additional room, consider adjusting the steering wheel or having someone else drive, if possible.  
\*\* If you're a passenger, move your seat back as far as possible.

**NO**  
Tension the lap and shoulder belts. Do not let the seat belt sag. Do not let the seat belt sag. Do not let the seat belt sag.  
Avoid letting your belly touch the steering wheel.

| Belt Fit Codes                    |                                  |   |
|-----------------------------------|----------------------------------|---|
| Volunteer #                       |                                  |   |
| At the clavicle, sternum, and lap | Follows NHTSA guidelines         | 1 |
|                                   | Does not follow NHTSA guidelines | 0 |

As body size increases...



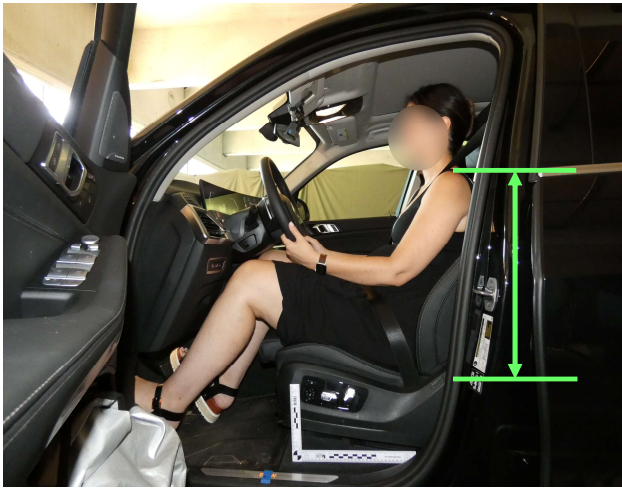
| Likelihood of proper fit |   |
|--------------------------|---|
| Clavicle                 | ↑ |
| Sternum                  | ↓ |

| Predictors                 | Clavicle |              | Sternum |              |
|----------------------------|----------|--------------|---------|--------------|
|                            | Odds     | p            | Odds    | p            |
|                            | Ratios   |              | Ratios  |              |
| Body Size (PC1)            | 1.78     | <u>0.020</u> | 0.65    | <u>0.008</u> |
| Lower Limb Extension (PC2) | 0.74     | 0.221        | 1.21    | 0.320        |
| Seated Torso Height (PC3)  | 2.76     | <u>0.003</u> | 2.11    | <u>0.002</u> |
| Relative Limb Angle (PC4)  | 0.54     | <u>0.032</u> | 1.47    | 0.103        |
| D-ring Position (PC5)      | 1.35     | 0.305        | 0.53    | <u>0.014</u> |
| Observations               | 76       |              | 76      |              |

\*One gestational age was missing; analytic sample is N-1=76.

| Odds Ratio Interpretation |                                |
|---------------------------|--------------------------------|
| Odds Ratio < 1            | Less likely to have proper fit |
| Odds Ratio > 1            | More likely to have proper fit |

As seated torso height increases...



| Likelihood of proper fit |   |
|--------------------------|---|
| Clavicle                 | ↑ |
| Sternum                  | ↑ |

| Predictors                 | Clavicle |                     | Sternum |                     |
|----------------------------|----------|---------------------|---------|---------------------|
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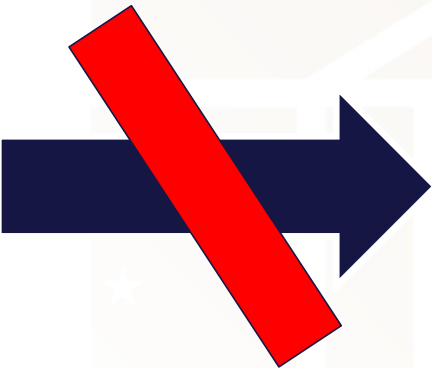
| Odds Ratio Interpretation |                                |
|---------------------------|--------------------------------|
| Odds Ratio < 1            | Less likely to have proper fit |
| Odds Ratio > 1            | More likely to have proper fit |

Summary

| With increasing...   | Likelihood of proper fit                          |   |
|----------------------|---------------------------------------------------|---|
| Body Size            | Clavicle                                          | ↑ |
|                      | Sternum                                           | ↓ |
| Seated Torso Height  | Clavicle                                          | ↑ |
|                      | Sternum                                           | ↑ |
| Relative Limb Angle  | Clavicle                                          | ↓ |
| D-ring Height        | Sternum                                           | ↓ |
| Lower Limb Extension | Not significantly associated with proper belt fit |   |

# What about the lap???

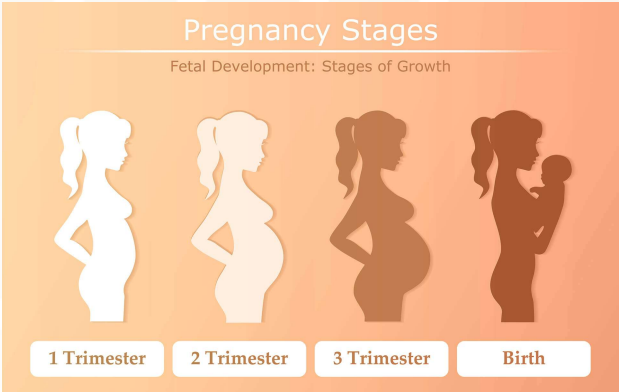
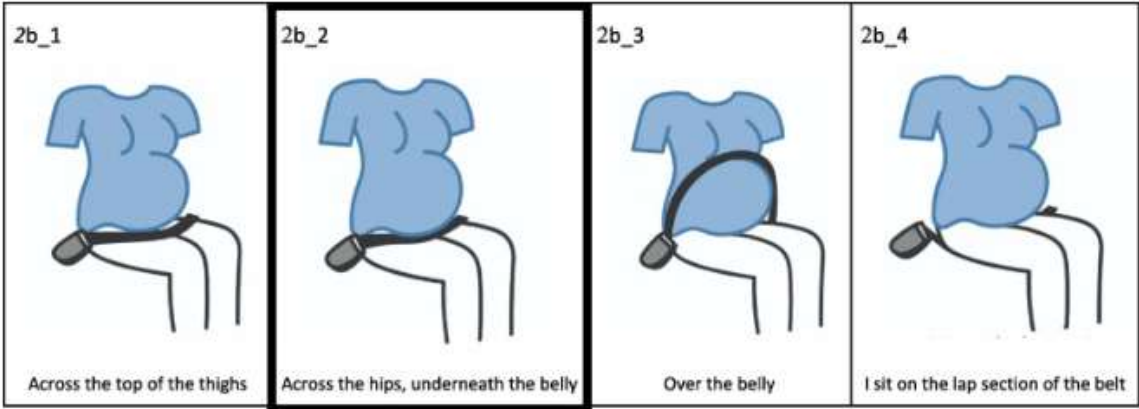
| PCs and Variables of Interest                 |
|-----------------------------------------------|
| Body Size                                     |
| Lower Limb Angle                              |
| Seated Torso Height                           |
| Relative Limb Angle                           |
| Vertical Distance between Shoulder and D-ring |
| Gestational Age                               |
| Maternal Age                                  |
| Model year                                    |
| Light Truck/SUV                               |
| Minivan                                       |
| Passenger Car                                 |



# Why no correlation with lap belt fit???



Lap belt fit might not be strongly influenced by stage of pregnancy, but rather by each person’s comfort and personal preference.



Ongoing Work – Relation between Safety Perceptions and Belt Fit

| With increasing...   | Likelihood of proper fit                          |   |
|----------------------|---------------------------------------------------|---|
| Body Size            | Clavicle                                          | ↑ |
|                      | Sternum                                           | ↓ |
| Seated Torso Height  | Clavicle                                          | ↑ |
|                      | Sternum                                           | ↑ |
| Relative Limb Angle  | Clavicle                                          | ↓ |
| D-ring Height        | Sternum                                           | ↓ |
| Lower Limb Extension | Not significantly associated with proper belt fit |   |



12:29

Q6. Choose one answer for each question.

Do you adjust the height of the shoulder belt strap to find the most comfortable?

☐ Always

☐ Most of the time

☐ Rarely

☐ Never

Was your seat belt comfortable prior to becoming pregnant?

How often do you wear your seat belt now?

Q7. Has your comfort level with your seat belt changed since you became pregnant?

Yes

## Other Questions - Public Guidance

- ▶ NHTSA guidance suggests moving the seat as rearward as possible (while maintaining control)



Comfortable Position



Rear-adjusted Position

Is that the best advice?

Rearward position = less knee bolster interaction = more reliance on belt & seat



National Highway Traffic Safety Administration

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#### WHAT'S THE RIGHT WAY TO WEAR MY SEAT BELT?



#### SHOULD I ADJUST MY SEAT?

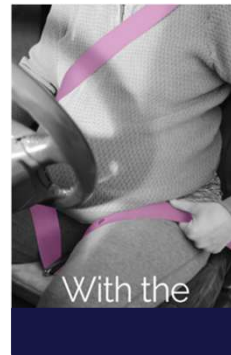


\* If you need additional room, consider adjusting the steering wheel or having someone else drive, if possible.  
\*\* If you're a passenger, move your seat back as far as possible.

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# Comfort Products

- ▶ Re-direct belt away from abdomen



## Challenges:

- Introduces slack into belt.
- Moves belt away from pelvis.

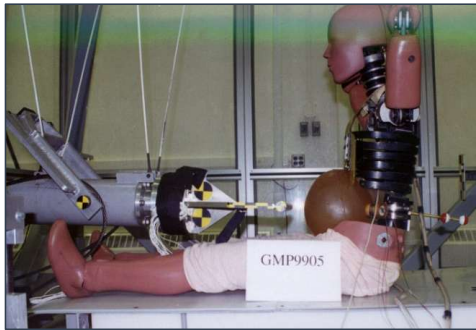


Anything that increases forward pelvis motion risks loading of steering wheel into abdomen (similar to an unbelted occupant)

# Pregnant Occupant Test Devices / Models

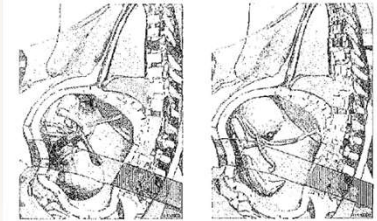
## MAMA-2B ATD

Rupp et al. 2001



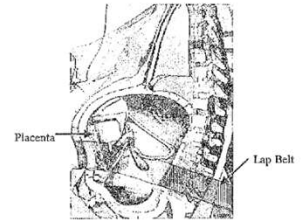
## THUMS v.1.0 AF05

Kitagawa et al. 2011



Case 1: Standard

Case 4: Fetus in Reverse Position



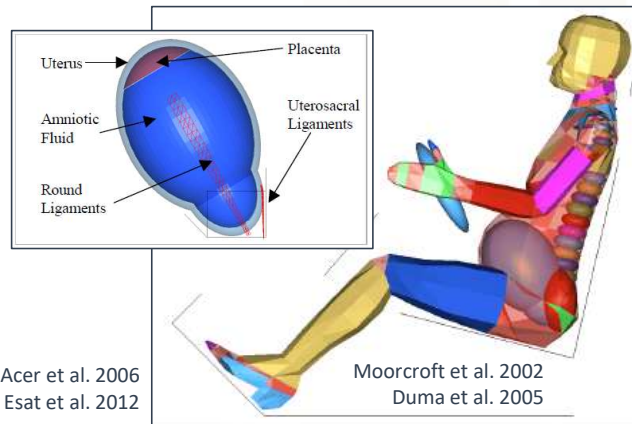
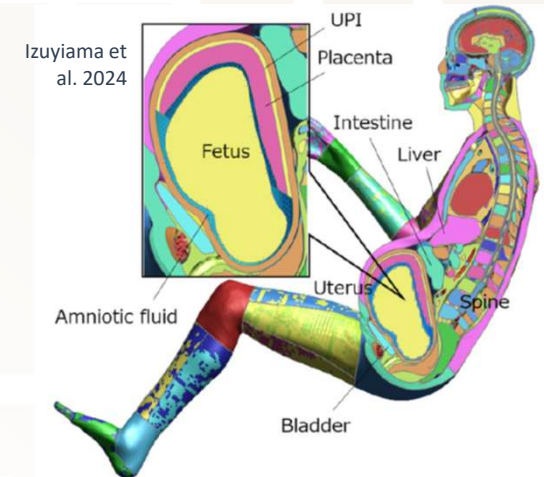
Case 5: Placenta at Anterior Uterus Wall

Challenge: How do we develop safety recommendations, evaluations?

### Limitations of Existing Tools:

- Size (limited to 5<sup>th</sup>% females)
- External & internal shape
- Intrauterine geometry, mechanics (for seated postures)

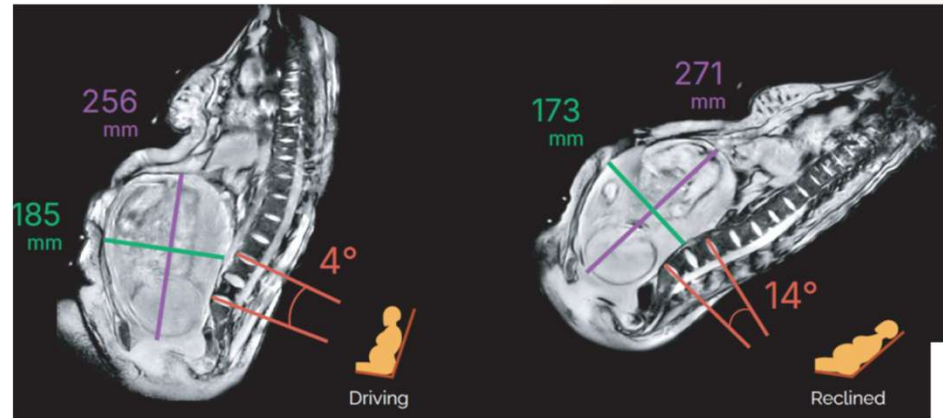
### Modified MADYMO 5<sup>th</sup> female

Acer et al. 2006  
Esat et al. 2012Moorcroft et al. 2002  
Duma et al. 2005

Izuyama et al. 2024

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# Information Gathering for Pregnant Occupant Modeling



Chung et al. 2026

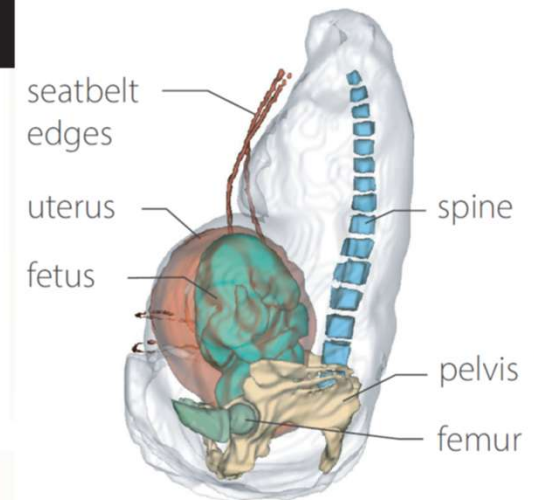
## Open MRI with Seated Pregnant Volunteers



THE UNIVERSITY OF BRITISH COLUMBIA  
School of Biomedical Engineering  
Faculties of Applied Science and Medicine



Collaborative Safety Research Center  
TOYOTA



Center for Applied Biomechanics

# SUMMARY

- Pregnant automobile occupants represent a unique challenge for automobile safety
  - Unique injury types
  - Protection of both the mother and the fetus
  - Belt use perceptions and guidance
  - Belt fit
- Potential opportunity for improvement through...
  - Communication of importance of proper seatbelt use
  - Continuing study of risk factors for injury to mother and fetus
  - Development of safety assessment tools for range of pregnant automobile occupant sizes and gestational age

# Seatbelt Fit and Safety Perceptions for Pregnant Automobile Occupants



Thank You!

Questions?

Email: [jlf3m@virginia.edu](mailto:jlf3m@virginia.edu)

Jason Forman, Keri-Anne Lue, Pavel Chernyavskiy  
*University of Virginia Center for Applied Biomechanics*

As the arms and legs become more parallel with respect to the ground ...



Likelihood of proper fit

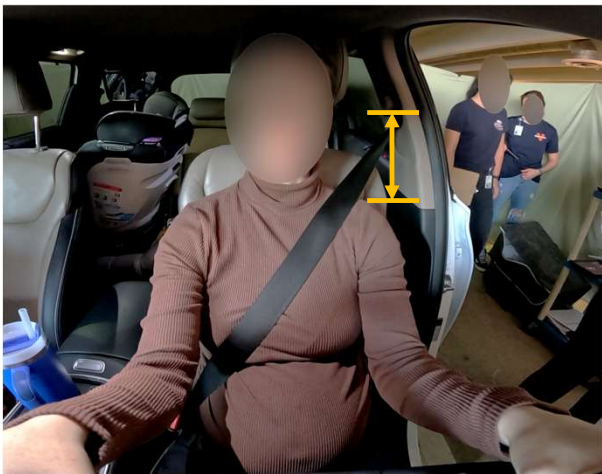
Clavicle

| Predictors                 | Clavicle |              | Sternum |              |
|----------------------------|----------|--------------|---------|--------------|
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|                            | p        |              | p       |              |
|                            | Ratios   |              | Ratios  |              |
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\*One gestational age was missing; analytic sample is N-1=76.

| Odds Ratio Interpretation |                                |
|---------------------------|--------------------------------|
| Odds Ratio < 1            | Less likely to have proper fit |
| Odds Ratio > 1            | More likely to have proper fit |

As the vertical distance between the shoulder and D-ring increases...



Likelihood of proper fit

Sternum

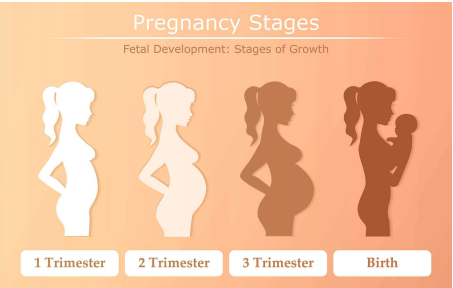


| Predictors                 | Clavicle |              | Sternum |                     |
|----------------------------|----------|--------------|---------|---------------------|
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Odds Ratio Interpretation

|                |                                |
|----------------|--------------------------------|
| Odds Ratio < 1 | Less likely to have proper fit |
| Odds Ratio > 1 | More likely to have proper fit |



↑  
2027  
2026  
2025



| Likelihood of proper fit |                          |
|--------------------------|--------------------------|
| Clavicle                 | Significantly associated |

\*No odds ratio due to non-linear gestational age

| Likelihood of proper fit |   |
|--------------------------|---|
| Sternum                  | ↓ |

| Likelihood of proper fit |   |
|--------------------------|---|
| Clavicle                 | ↓ |

| Predictors      | Clavicle    |              | Sternum     |              |
|-----------------|-------------|--------------|-------------|--------------|
|                 | Odds Ratios | p            | Odds Ratios | p            |
| Gestational Age |             | <u>0.038</u> |             | 0.195        |
| Maternal Age    |             | 0.218        |             | 0.783        |
| Model year      | 0.77        | 0.525        | 0.44        | <u>0.024</u> |
| Light Truck/SUV |             | Ref.         |             | Ref.         |
| Minivan         | 0.03        | <u>0.034</u> | 0.52        | 0.547        |
| Passenger Car   | 0.19        | 0.081        | 2.49        | 0.285        |
| Observations    | 76          |              | 76          |              |

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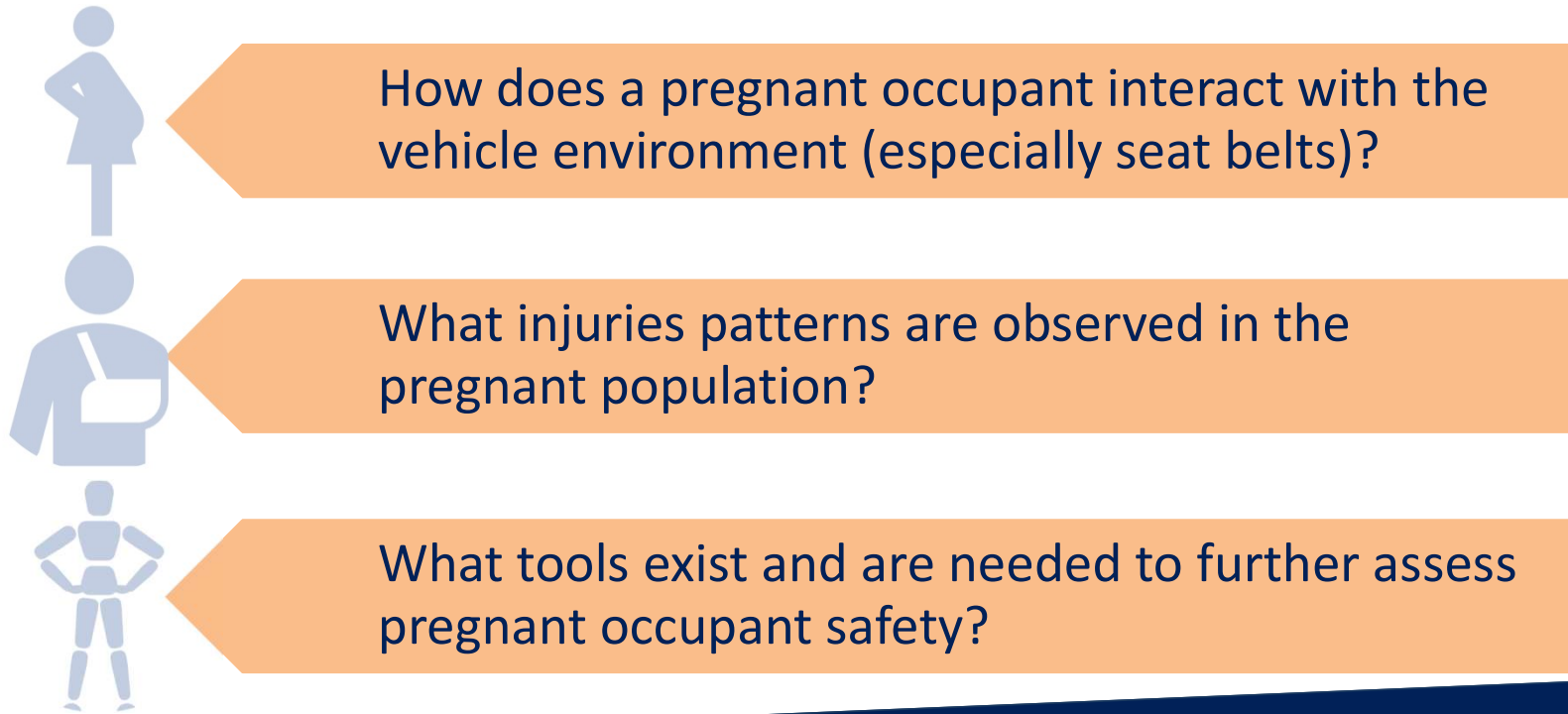
## ANNUAL MVC INJURY ESTIMATES (U.S.)

| Statistic      | Pregnant automobile occupants               | Children (<=14) | All other |
|----------------|---------------------------------------------|-----------------|-----------|
| Population     | 2.96 mil                                    |                 |           |
| All crashes    | 84-215 k                                    |                 |           |
| Injury crashes | 27-66 k                                     |                 |           |
| Fatalities     | 290-770 (maternal)<br>550-1,420 (perinatal) |                 |           |

## ANNUAL MVC INJURY ESTIMATES (U.S.)

| Statistic      | Pregnant automobile occupants               | Children (<=14)    | All other |
|----------------|---------------------------------------------|--------------------|-----------|
| Population     | 2.96 mil                                    | 60.3 mil           | 263 mil   |
| All crashes    | 84-215 k                                    |                    | 9.1 mil   |
| Injury crashes | 27-66 k                                     | 139 k <sup>1</sup> | 2.8 mil   |
| Fatalities     | 290-770 (maternal)<br>550-1,420 (perinatal) | 1,093 <sup>1</sup> | 41,000    |

# SAFETY CONSIDERATIONS FOR PREGNANT OCCUPANTS



# SAFETY CONSIDERATIONS FOR PREGNANT OCCUPANTS



How does a pregnant occupant interact with the vehicle environment (especially seat belts)?



Hesitancy?  
Belt Use  
Rates?

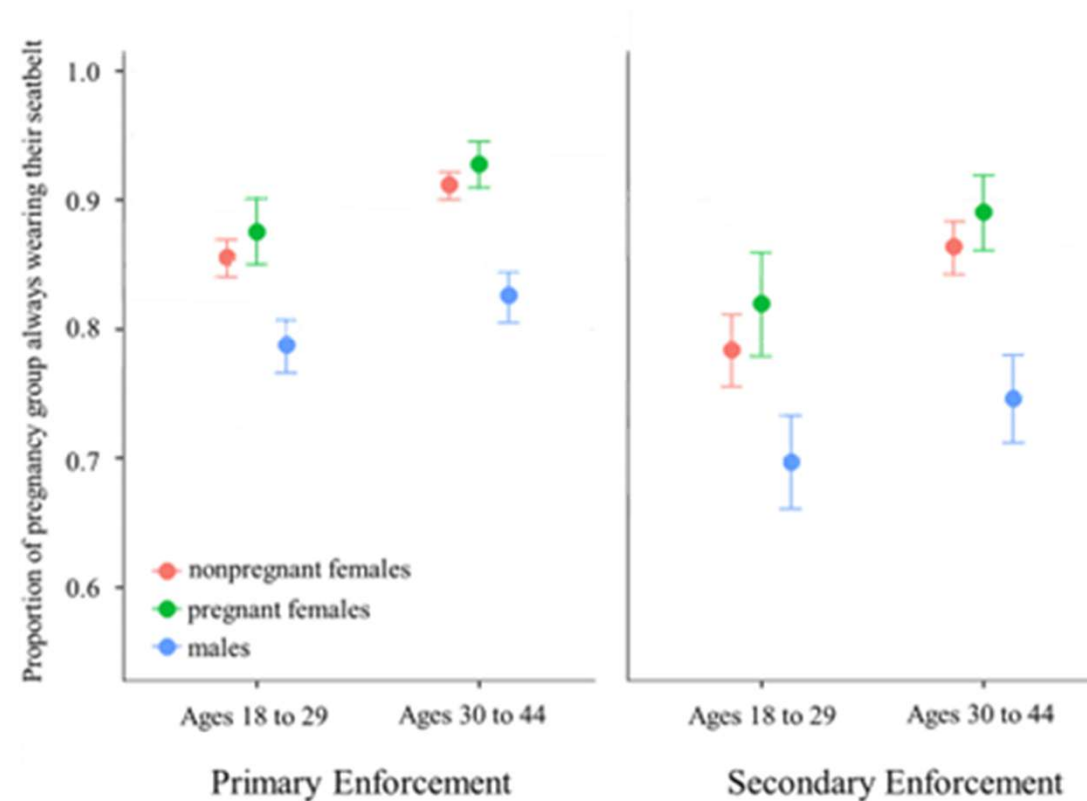
# DATASET & ANALYSIS

- BRFSS 2011-2024

|                    |       | Female (not pregnant) | Female (pregnant) | Male    |
|--------------------|-------|-----------------------|-------------------|---------|
| Response Counts    |       | 585,543               | 23,356            | 540,426 |
| % Age 18-29        |       | 33%                   | 49%               | 40%     |
| % Always Wear Belt | 18-29 | 84%                   | 85%               | 77%     |
|                    | 30-44 | 90%                   | 91%               | 81%     |

- Bayesian Regression to Examine Geographic, Temporal, & Enforcement Trends

# AGE TRENDS IN SEATBELT USE



Averaged over time and state

# Behavioral Risk Factor Surveillance Survey (BRFSS)

Telephone survey dataset on health-related risk behaviors, chronic health conditions, and use of preventive services.

Completes more than 400,000 interviews per year



**Section 16: Seatbelt Use**

---

**16.1** How often do you use seat belts when you drive or ride in a car? Would you say— (169)

**Please read:**

- 1 Always
- 2 Nearly always
- 3 Sometimes
- 4 Seldom
- 5 Never

**Do not read:**

- 7 Don't know / Not sure
- 8 Never drive or ride in a car
- 9 Refused

**CATI note:** If Q16.1 = 8 (Never drive or ride in a car), go to Section 18; otherwise continue.

| Questionnaire Response | Seat Belt Use Classification |
|------------------------|------------------------------|
| "Always"               | 1-Always                     |
| "Nearly Always"        | 0-Not Always                 |
| "Sometimes"            | 0-Not Always                 |
| "Seldom"               | 0-Not Always                 |
| "Never"                | 0-Not Always                 |
| Other                  | excluded                     |

# American College of Obstetricians and Gynecologists

## Why is it important to wear a seat belt when I travel during pregnancy?

“Although your fetus is protected inside your body, you should wear a lap and shoulder belt every time you travel while you are pregnant for the best protection—even in the final weeks of pregnancy. You and your fetus are much more likely to survive a car crash if you are buckled in.”

## How should I wear a seat belt while I am pregnant?

- Buckle the lap belt below your belly so that it fits snugly across your hips and pelvic bone.
- Place the shoulder belt across your chest (between your breasts) and over the mid-portion of your collar bone (away from your neck).
- Never place the shoulder belt under your arm or behind your back.
- Pull any slack (looseness) out of the belt.
- If you are in an accident, seek medical attention right away, even if you are not injured.

# Pregnancy Risk Assessment Monitoring Survey (PRAMS)

During a prenatal visit with a clinician, the following percentage of post-partum women recalled counseling regarding...

**Drinking alcohol**

72%

**Smoking cigarettes**

71%

**Using seat belt**

???

Presented to the Society of Maternal Fetal Medicine, 2024 (Gallaher et al.)

# Pregnancy Risk Assessment Monitoring Survey (PRAMS)

During a prenatal visit with a clinician, the following percentage of post-partum women recalled counseling regarding...

**Drinking alcohol**

72%

**Smoking cigarettes**

71%

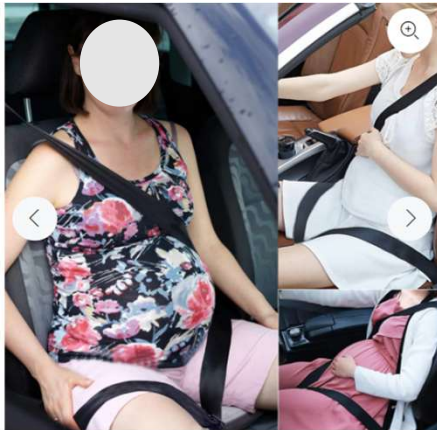
**Using seat belt**

54%

Presented to the Society of Maternal Fetal Medicine, 2024 (Gallaher et al.)

# Comfort Products

- Re-direct belt away from abdomen



8 lbs. of  
high tensile  
stainless steel



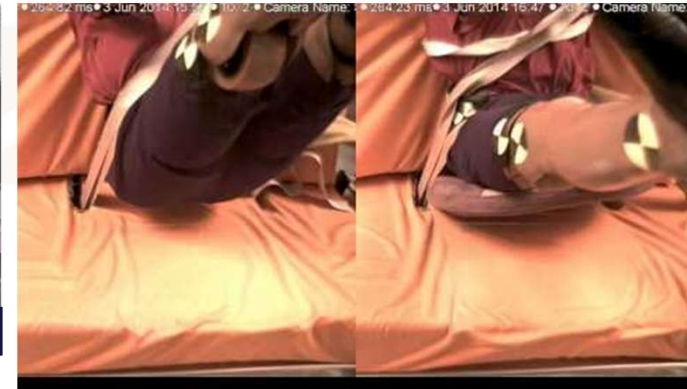
+

comfortable  
foam cushion



=

crash tested



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