# Wheelchair Transportation Principles I: Biomechanics of Injury

Gina Bertocci, Ph.D.
&
Douglas Hobson, Ph.D.

Department of Rehabilitation Science and Technology
University of Pittsburgh

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This presentation (Principles-I) is intended for persons seeking to understand the fundamental principles of occupant injury causation resulting from vehicle impacts.

Principles II-applies the principles of this presentation to injury prevention of wheelchair-seated persons in the event of a vehicle impact.

# Learning Objectives

To become familiar with the following concepts:

- the incidence of auto injuries and fatalities,
- most common directions of vehicle impacts,
- basic biomechanical principles of occupant injury causation.

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## Magnitude of Problem
## Motor Vehicle Casualties

- 40,000+ people killed each year.
- 1.25 Million people injured and sent to emergency room each year.
- Comprehensive cost to society each year = $120 Billion
- 1.3 Million years of potential life lost each year.

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## Estimated # of Wheelchair Users Injured or Killed by Type of Vehicle Involved (1991-1995)

| Type of Vehicle | Estimated # of persons | % Total |
|---|---|---|
| Van | 3410 | 48% |
| Passenger Car | 2153 | 30% |
| Bus | 856 | 12% |
| Ambulance | 506 | 7% |
| Truck | 196 | 3% |
| Total | 7121 | 100% |

**Refer: US DOT, NHTSA**

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# Injury Statistics

| Injury Producing Acitivity | Estimated # of Persons | % Total |
|---|---|---|
| Improper or No Securement | 2494 | 35% |
| Collision Between WC & Motor Vehicle | 1819 | 26% |
| Lift Malfunction | 1366 | 19% |
| Transfer to/From Motor Vehicle | 1035 | 15% |
| Falling On/Off Ramp | 407 | 6% |
| Total | 7121 | 100% |

Estimated # of W/c users injured or killed, grouped by injury producing activity (1991-1995)

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(see note below)

Note: that improper use of securement devices results in largest cause of injuries

# Crash Impact Direction vs Fatalities

| Direction of Impact | Cars | School Buses |
|---|---|---|
| Front | 48.3% | 55.9% |
| Side | 28.5% | 14.7% |
| Rear | 3.3% | 0% |
| Other,unknown | 19.9% | 29.4% |

From NHTSA FARS Database

- **Approx 50% of Crashes Resulting in Fatality or Serious Injury are Frontal Crashes**

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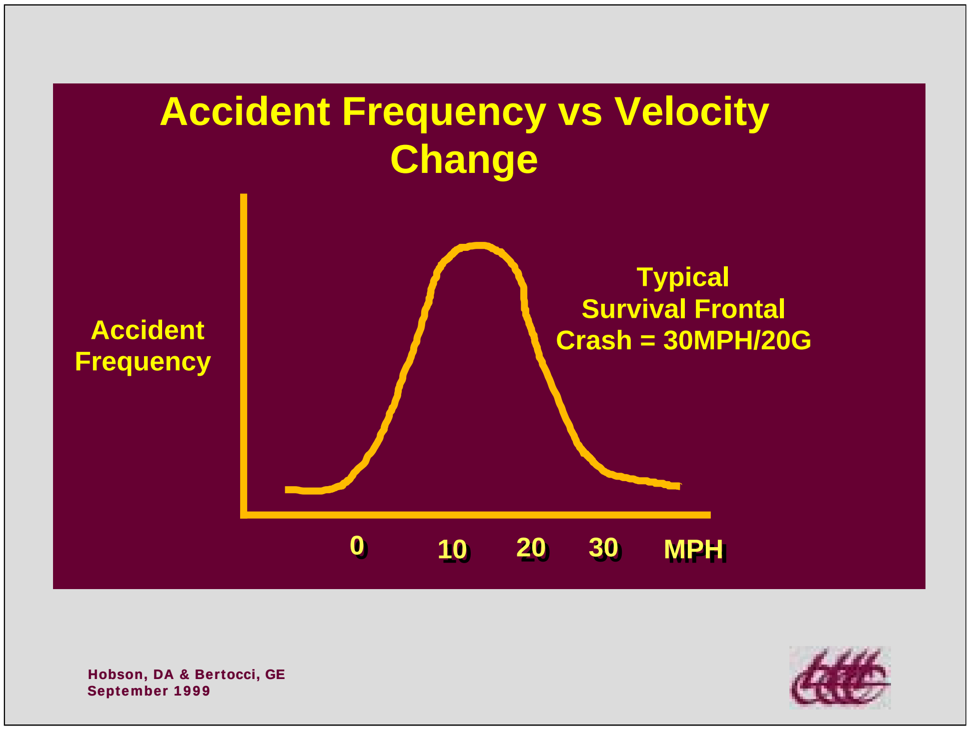
(see note below)

Note:frontal impacts by far represent the largest--48+% # of fatal crashes




Most accidents occur at a delta “v” of about 15 MPH. Of course, many occur at both lower and higher speeds. A delta “V” value of 30MPH (48KPH) and a 20G deceleration pulse is survivable and therefore used as the test benchmark for small vehicle safety testing

## Occupant Orientation in Vehicle

- Rearward Facing
  - Safest in frontal crash with energy absorbing material.
  - Not well accepted or always practical
- Side Facing
  - Least safe in frontal crash
  - Difficult to provide effective restraint for frontal crash
  - Assymetric body movement increases injury severity
- Forward Facing
  - Safest in frontal crash
  - Practical & acceptable

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(see note below)

Neither the body nor the wheelchair are well designed to sustain the crash loads incurred in a side-facing frontal impact. Why?

## Crash Dynamics

- INJURY RISK:
  - Proportional to "VELOCITY CHANGE"
  - Inversely proportional to "TIME over which VELOCITY CHANGE occurs "
- Occupant restraints serve to reduce injury risk by:
  - Increasing time which velocity change occurs,
  - Preventing body impact with vehicle interior

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# Newton's 2nd Law

- F = MA
  - M = mass of body
  - A = acceleration; A = Velocity/Time
  - F = force applied to body
- Also written as....
  - F = M (V/T)

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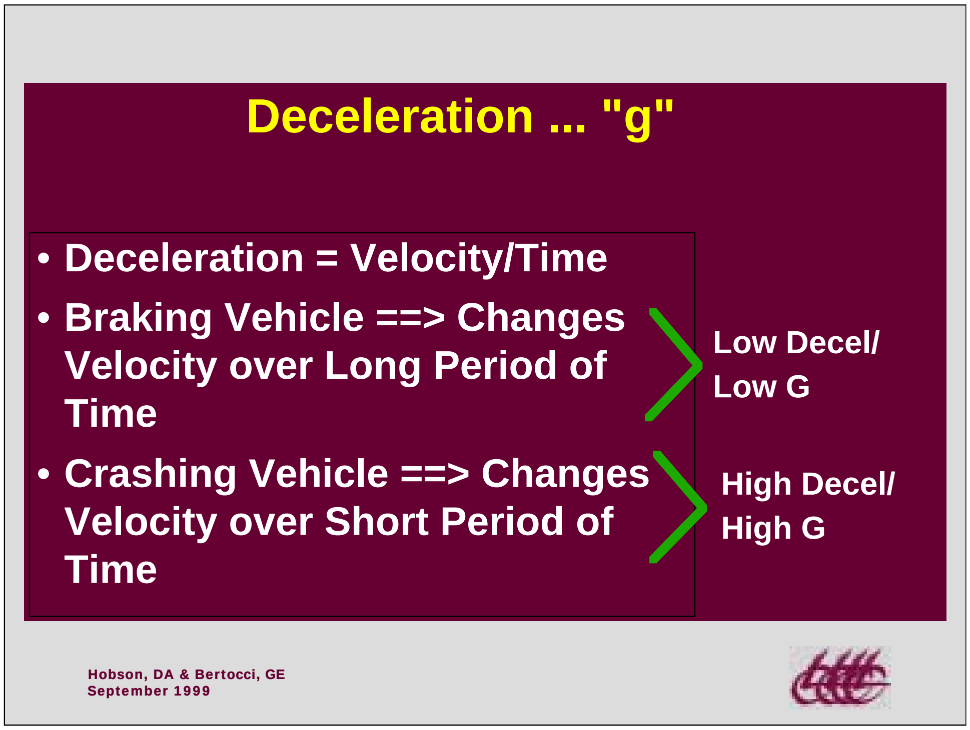
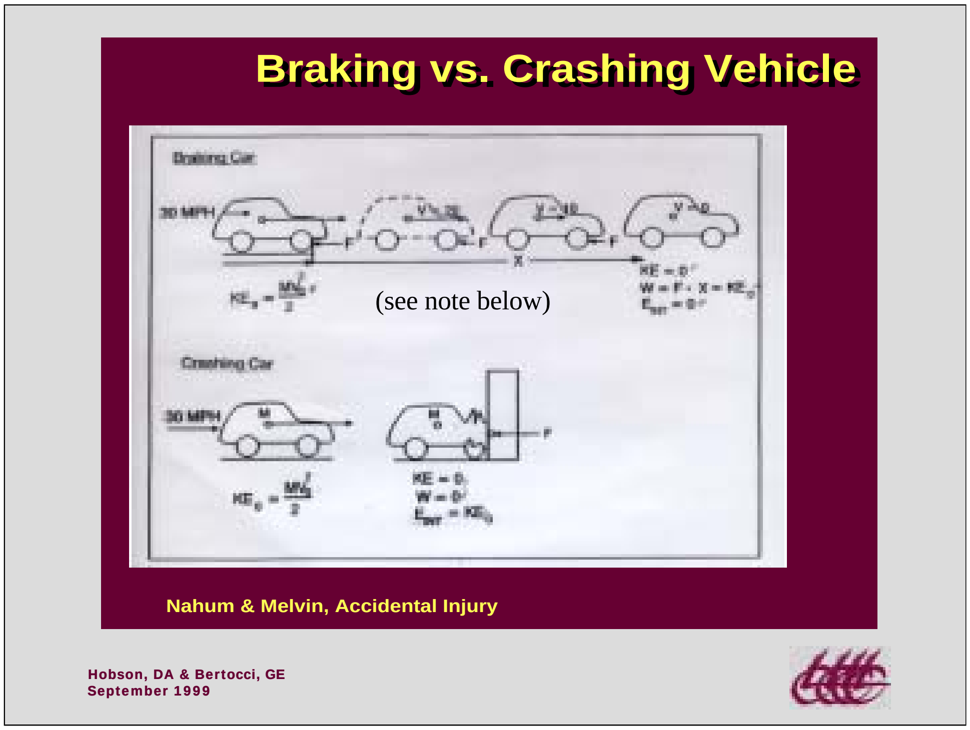
(see note below)

F=MA gives the relationship between the mass and the deceleration (change in velocity) which allows the analysis and computation of the forces that will be generated during a crash event. Injury protection is all about being able to dissipate or 'ride down' the impact forces in such a way that the occupant will not experience forces that will produce injury.



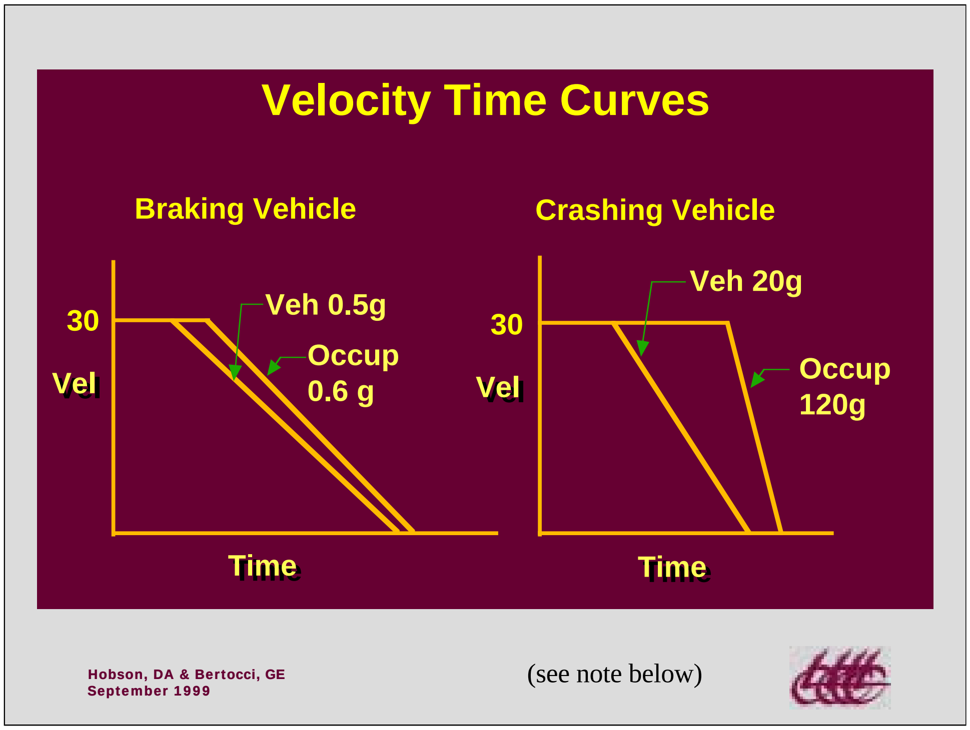

It is high ‘g’ loads that produce injury. Therefore the a goal of occupant protection is to keep ‘g’ loads within tolerable levels



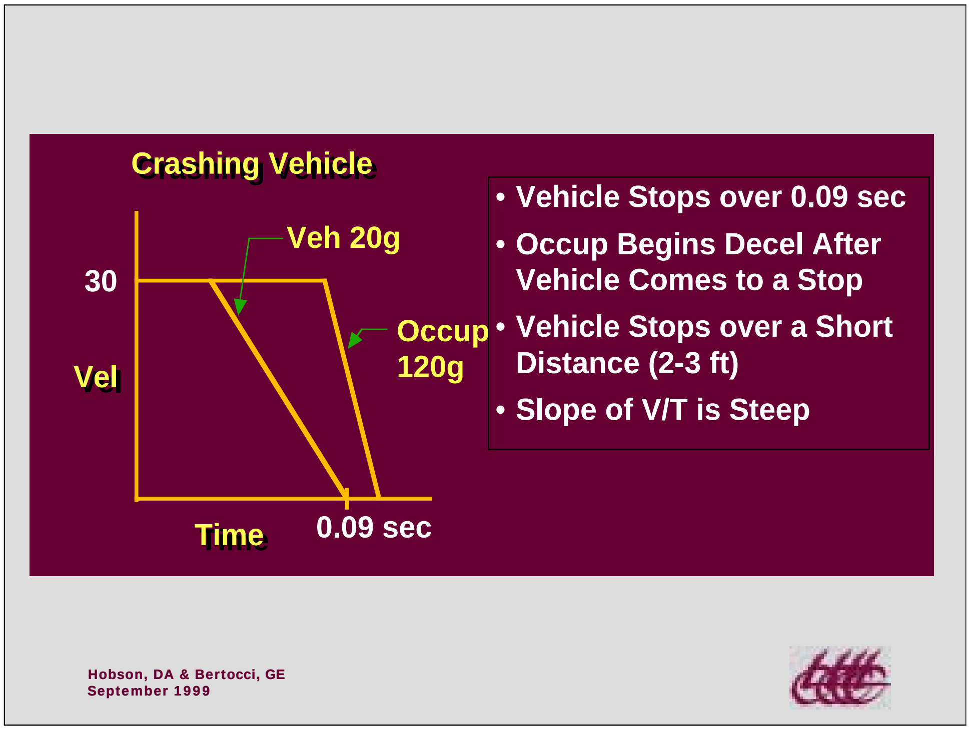

In a 30mph vehicle under normal braking conditions, the kinetic energy is dissipated by the brakes over a relatively long time period, i.e. 3-4 seconds..

In the 30mph crashing vehicle the same kinetic energy is dissipated over a much shorter time, i.e. 100msecs.

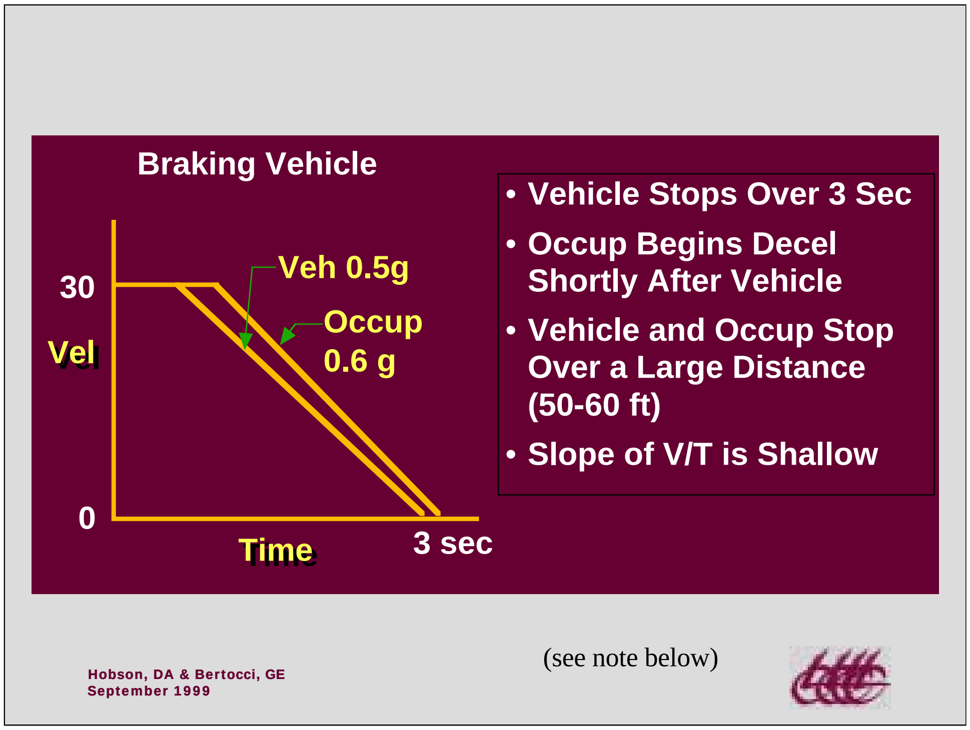
Result: Deceleration forces (‘g’) incurred by both the vehicle and its passengers are much higher in s crash. Without adequate injury protection the incurred loads are sufficient to produce severe injury, if not fatalities.



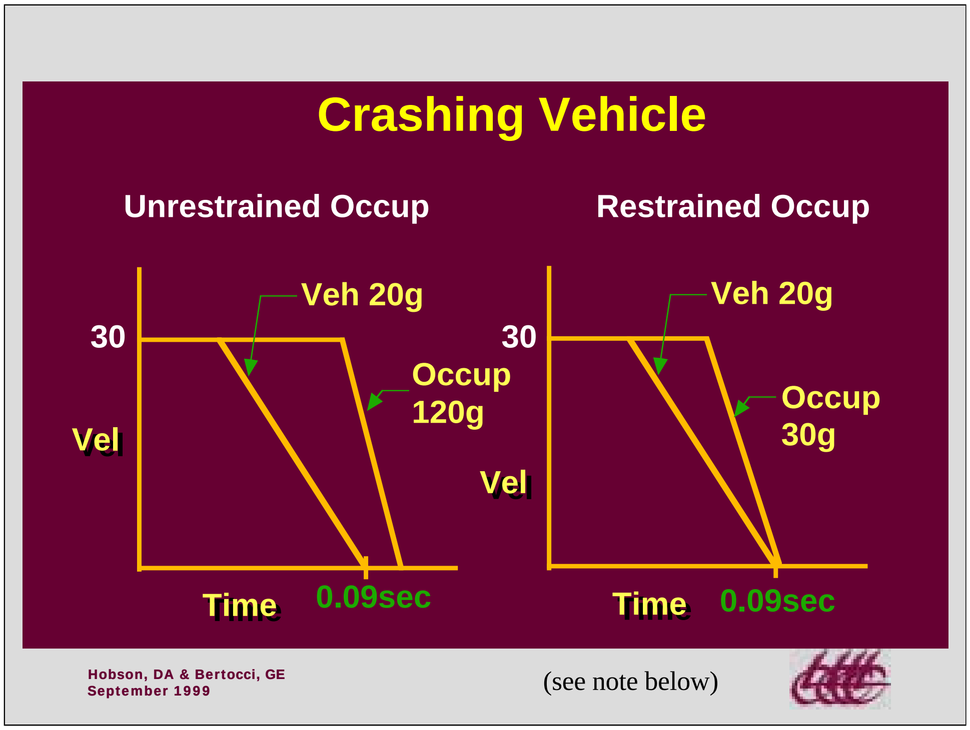

Note the difference in vehicle and occupant 'g' in braking vehicle vs. crashing vehicle




Note that in a crashing vehicle that the occupant deceleration occurs over a shorter time period (steeper slope)than the vehicle. As a result the occupant incurs a higher "g" than the vehicle.




In a braking vehicle both vehicle and occupant stop over approximately the same (longer) time period. Therefore both incur a relatively low 'g', with the the occupant only slightly higher then the vehicle (.1g).




In a crashing vehicle, the restrained occupant 'rides down the crash.' The result is that the restrained occupant incurs about 90g less deceleration than an unrestrained occupant. Also note that in the restrained case both vehicle and occupant stop at the same time.

## Injury Risk

- Proportional to VELOCITY CHANGE
  - 30 to 0 MPH ==> Lower Risk
  - 60 to 0 MPH ==> Higher Risk
- Injury Risk Decreases as Time Over WHich Velocity Change Occurs Increases
  - Braking Car (30 MPH)
  - Crashing Car (30 MPH)

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Note: there are also other risk factors. If you are heavy or tall you are more likely to strike an interior surface. If you are small, the restraints may not be as effective due to poor belt fit.

## Occupant Restraints Reduce Injury Risk By.......

- Increasing the Time Over Which the Occupant Comes to a Stop
  - Decreasing Deceleration...or "G's"
- Decreasing Occup Forward Travel
  - Reduces Risk of Impact w/Vehicle Surface ==>Reduces Risk of Injury !!

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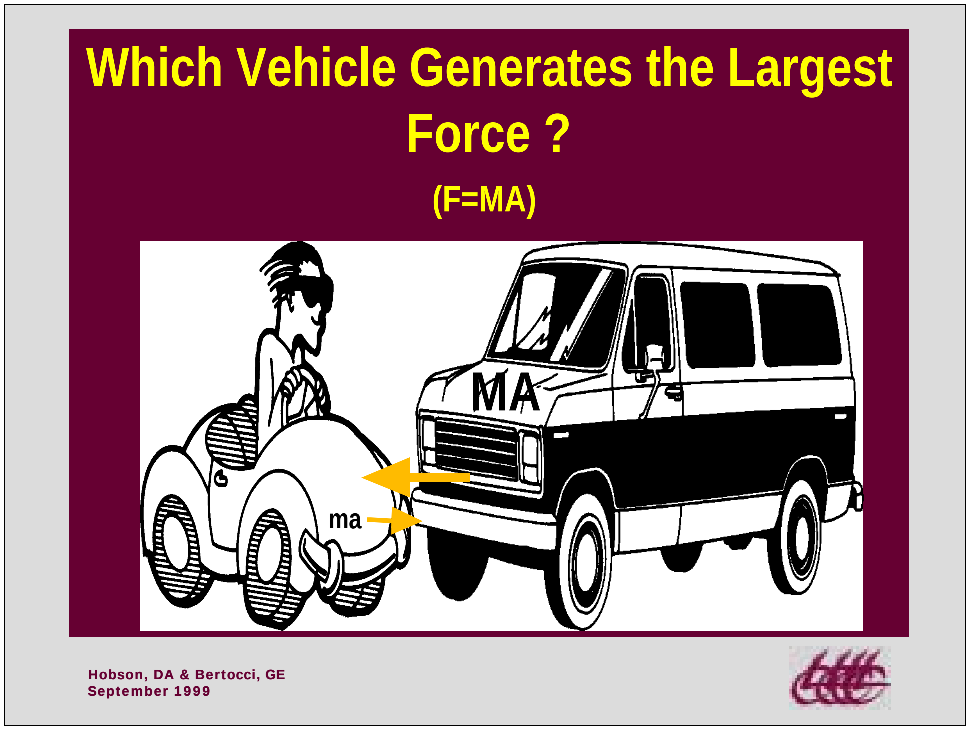
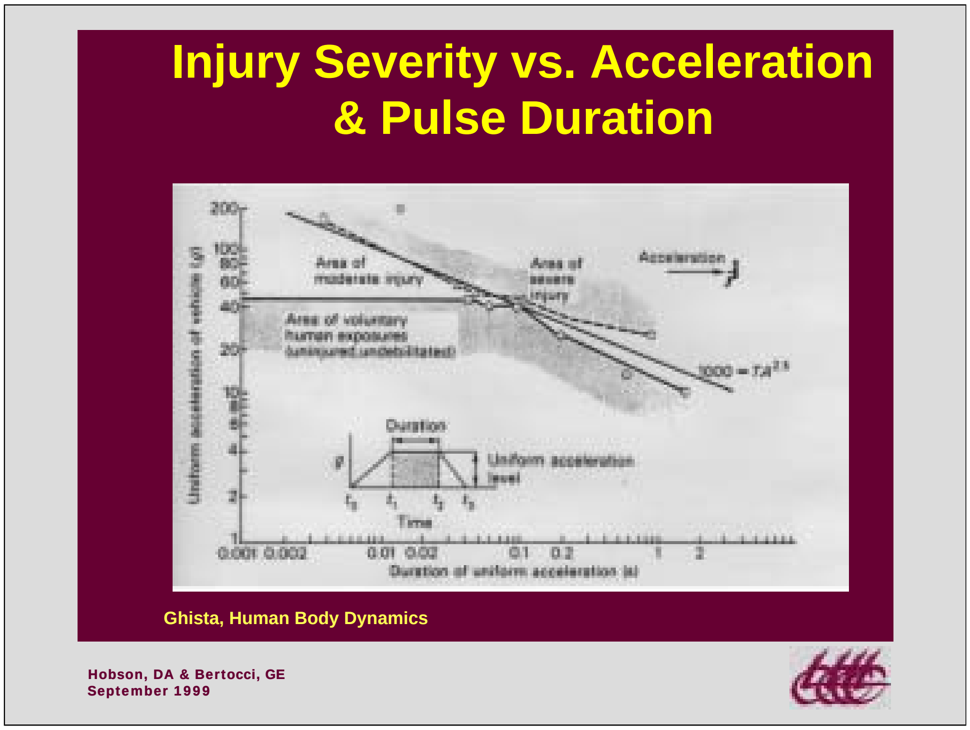



The time taken to stop in a crash is also dependent on the mass and design of both vehicles. Clearly, the passengers in a small car will fare better if their vehicle impacts a vehicle of the same or smaller mass, in contrast to vehicle with a much larger mass.

Striking an incompressible fixed object, such as a bridge column, can generate very high deceleration forces.




This complicated looking diagram basically tells us that the longer high ‘g’ loads are applied to the body in an impact situation the more likely severe injury will occur….or we can say that we are able to tolerate lower ‘g’ levels for a longer period of time without injury.

## Vehicle Design

- Occupant impact loads are also based on vehicle design features, such as:
  - Energy absorbing/collapsing structures
  - Padded interior surfaces
  - Occupant proximity to interior surfaces
  - Seat design & height from ground
  - Occupant restraints
  - Airbags

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## Anthropomorphic Test Devices - ATD

- Design to biofedelic representations of humans in terms of response to a crash. Efficacy depends upon:
  - accuracy of human representation
  - measurement of ATD responses
  - correlation between measured response & injury potential
- ATD family..
  - Hybrid III - 50th percentile male-(most common)
  - Small female - 5th percentile
  - Large male - 95th percentile

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# ATD's continued…

- Child Dummies:
  - 6 month - CRABI- used for child restraint-air bag interaction
  - 3 yr. old-infant seats
  - 6 yr. old-smallest used in W/C standards.
- SID - Side Impact Dummy - Hybrid II w/ modified upper torso - FMVSS 214
- BIOSID - Modified Hybrid III

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# Hybrid II-III ATDs

- Hybrid II - 1972 developed by GM & specified by FMVSS 208
- Hybrid III - 1986 accepted for FMVSS 208
- Developed for frontal crash testing
- Evaluates effectiveness of occupant restraints
- Instrumentation: (ref. SAE 770938)
  - Head - triaxial accelerometer
  - Head/Neck - shear & axial force, moments
  - Chest - triaxial acceleration, sternal deflection
  - Pelvis - triaxial acceleration
  - Femur - axial force

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## Hybrid III continued..

- Knee - tibia-femur displacement, force
- Tibia - moments, shear & axial force
- additional optional instrumentation available.

- Hybrid III Validation
  - Anthropometry - human data of seated position
  - Head - drop test - head acceleration
  - Neck - sled tests - moment vs. angle for flexion & extension
  - Thorax - blunt frontal impact - force-deflection characteristics

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A great deal of research and validation has been done in an attempt to develop an ATD that will both, accurately represent response and measure the loads incurred during a crash event. A comparison between the measured loads for a specific crash event to those loads known to produce body injury allows the determination of the effectiveness of a specific occupant protection system.

# Crash Severity Benchmark

- 20g/30 mph - Frontal Impact Sled Test
- Used by:
  - FMVSS Occupant Protection-Auto Industry
  - SAE J2249 WTORS-Wheelchair Tiedowns
  - ANSI/RESNAWC-19- Wheelchairs Used as Motor Vehicle Seats
- Equivalent to that seen in a passenger size vehicle
- It is a survivable crash severity

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