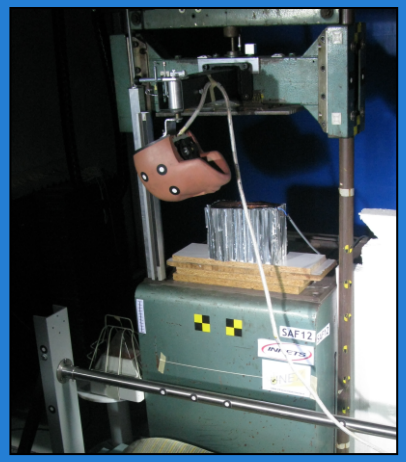

Passive Safety of Standing Passengers in Public Transportation

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Biomechanics and Impact Mechanics Laboratory (LBMC),

UMR_T9406

16/11/2011

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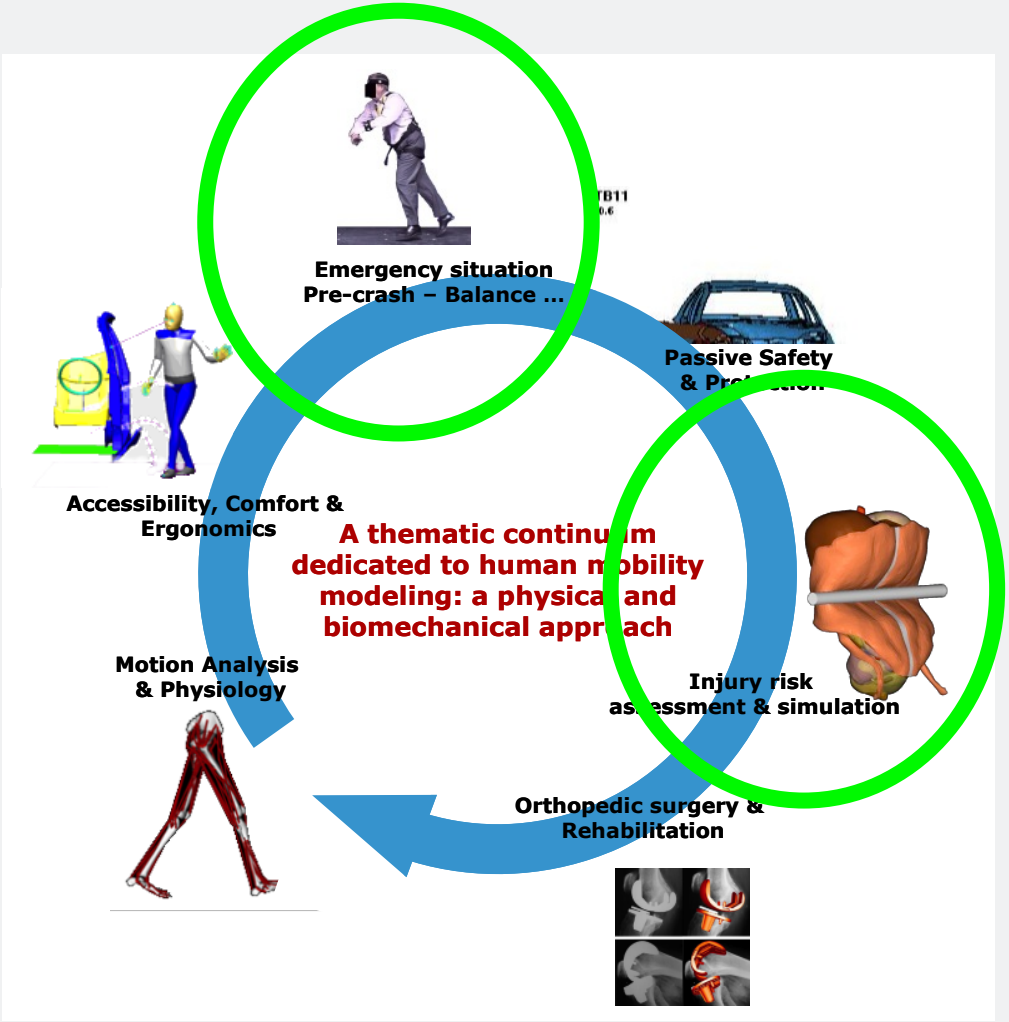
UNIVERSITÉ DE LYON

Lyon 1

The Biomechanics and Impact Mechanics Laboratory (LBMC, UMR_T 9406)



Context and Objectives

- Problematics: Standing passengers in public transportation are vulnerable: in the case of a sudden deceleration
  - They may be subjected to movements of great amplitude
  - Possible injuries due to impacts on interior fittings
- … A worsening problem:
  - More and more standing passengers ← “open spaces”, improved accessibility, …
  - An aging population
  - Road traffic more and more complex,
    - share the traffic with road vehicles,
    - especially at crossroads

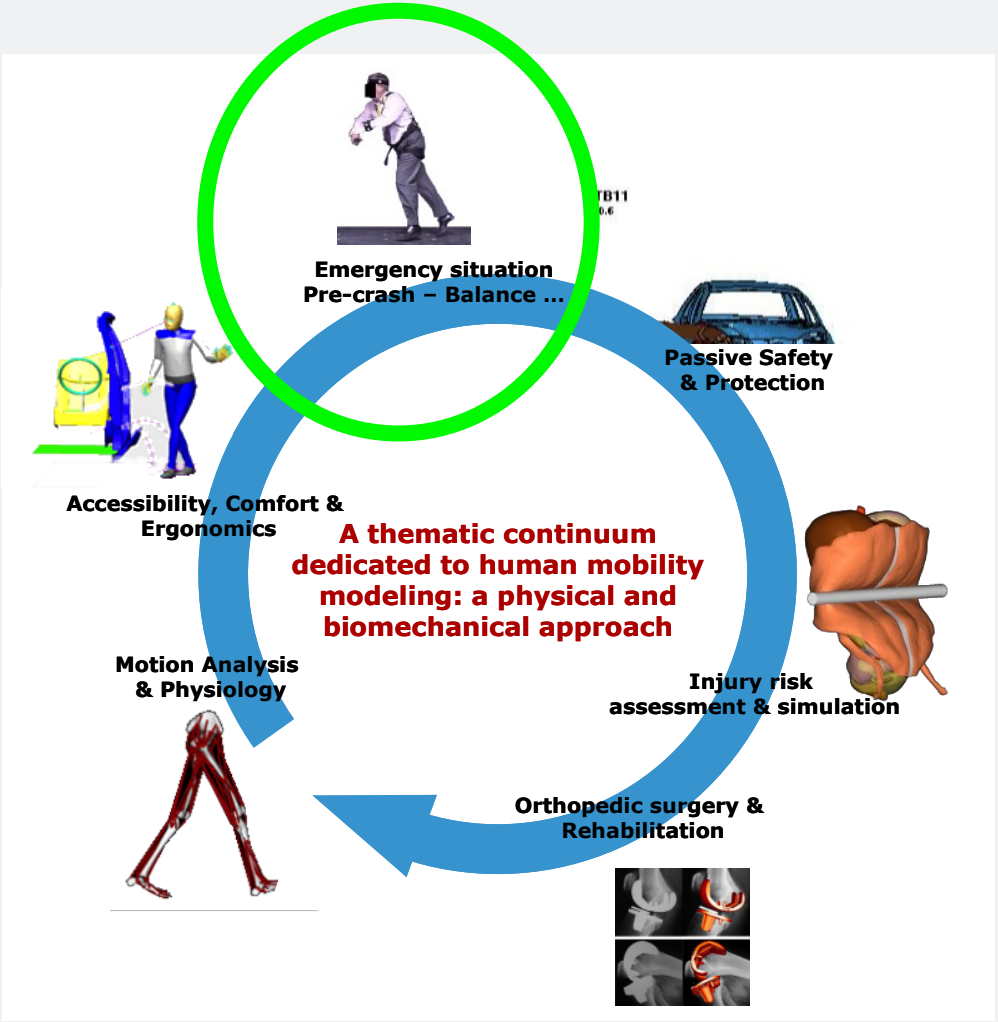
Context and Objectives

Objectives *[SafeInteriors project]*

- Determine trends of standing occupants kinematics under emergency braking conditions
- Evaluate injury risk when head impacts a grab pole during a crash

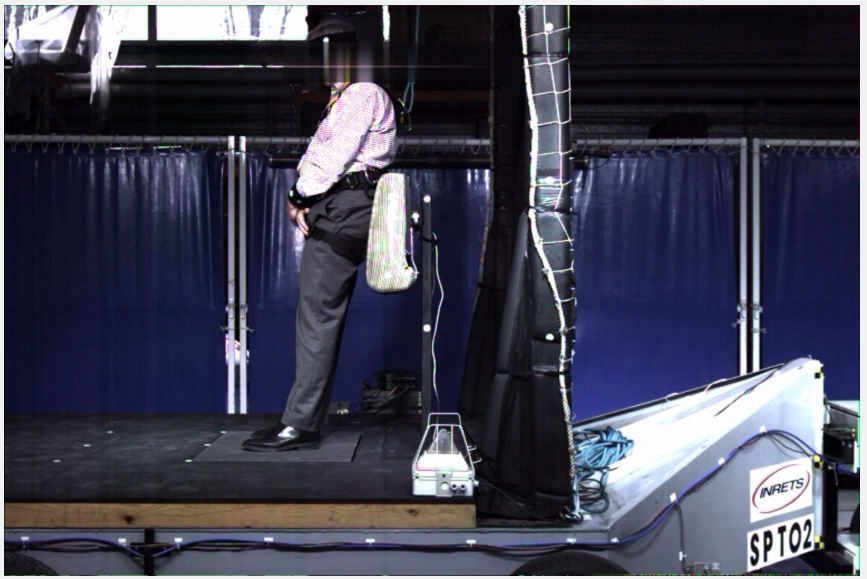
➔ Recommendations to designers concerning interior layout and acceleration/braking features of public transports

Standing occupants kinematics



Context and Objectives

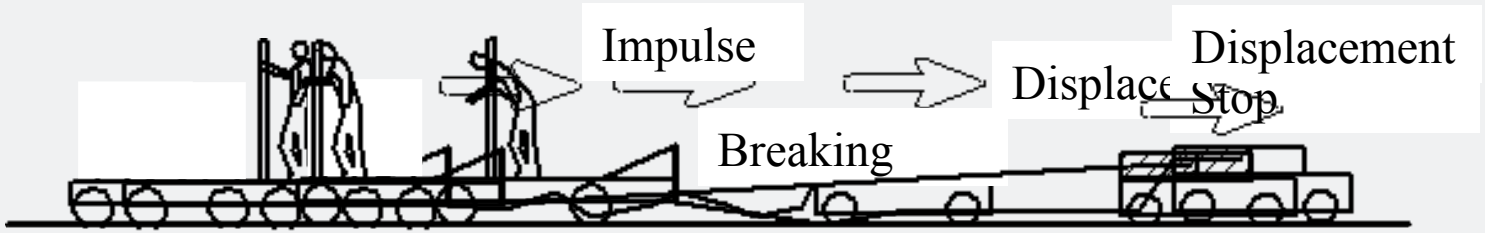
Emergency braking: need to perform testing with live human subjects



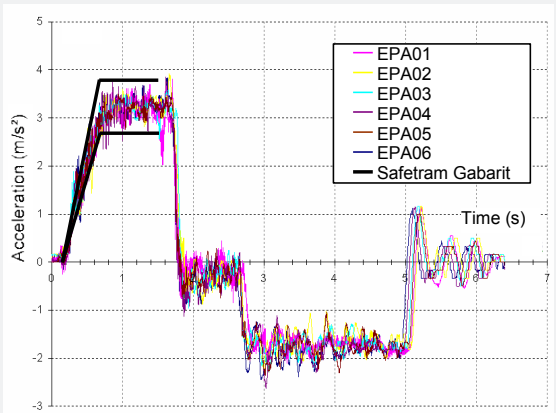
Importance of the reactivity in the kinematics

Standing occupants kinematics: *methods*

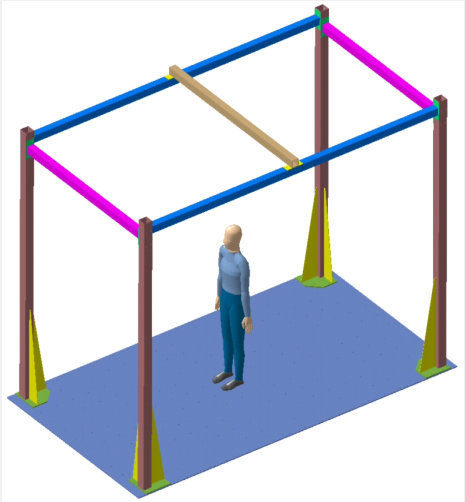
Volunteers are standing on a mobile platform initially still



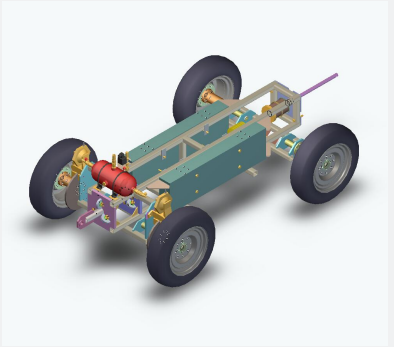
The platform is suddenly moved towards the subject without notice



Platform acceleration pulse measured for 6 tests and the theoretical corridor defined for urban and peri-urban trams



Mobile platform



Launching cart

Standing occupants kinematics: *methods*

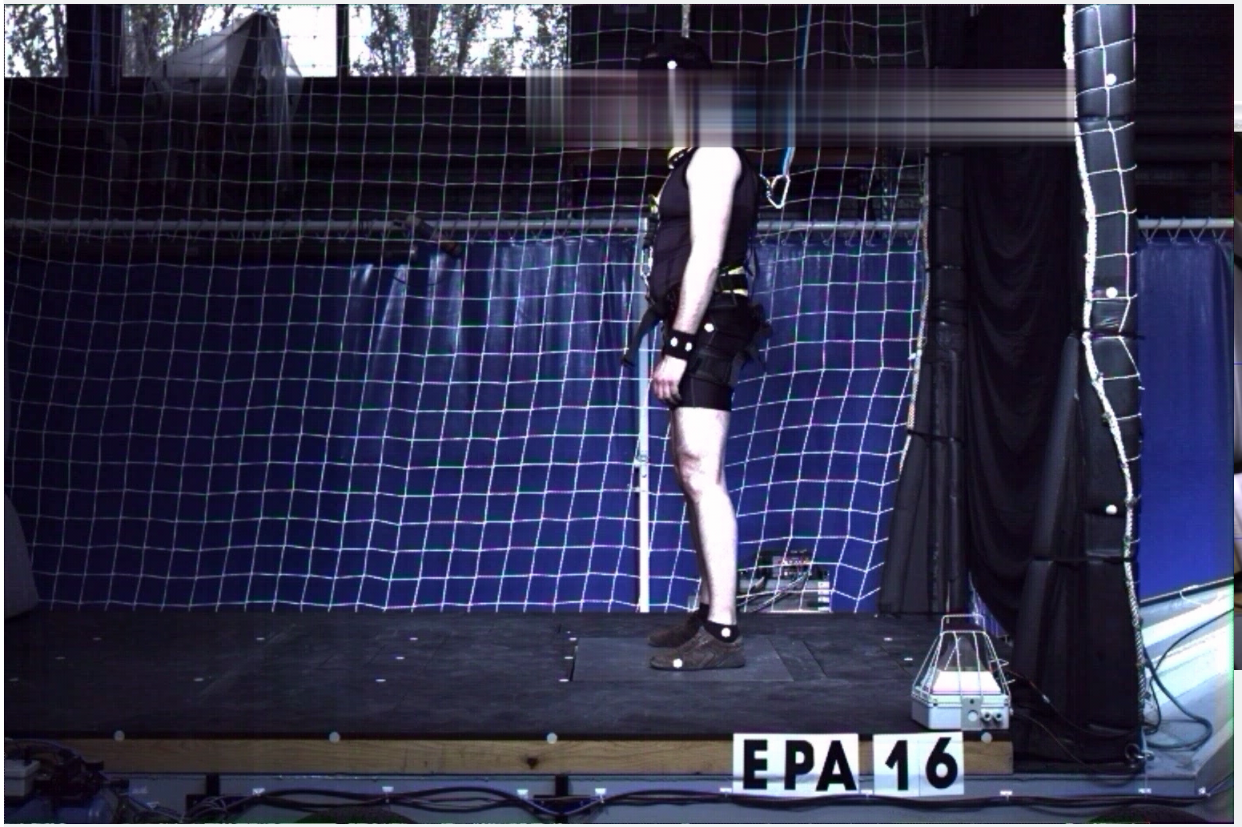
- 10 young healthy males
  - Individual protection (harness, mattress, net)
- 6 configurations mixing orientation of body and use of a buttock support and grabpole

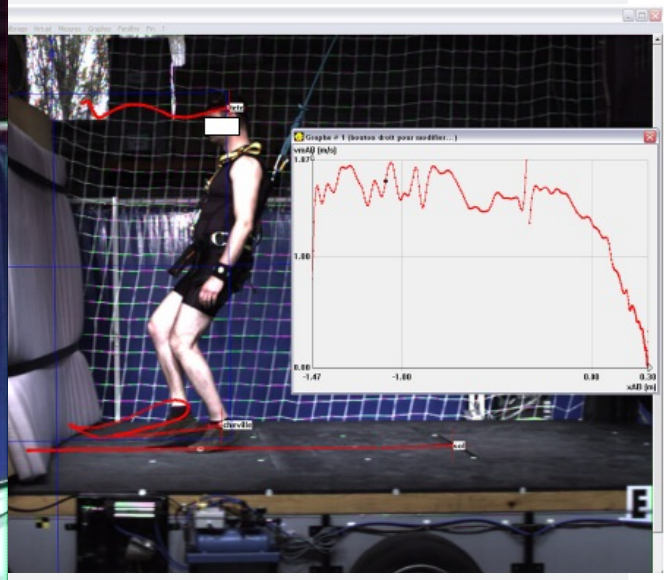
rearward facing | *forward leaning against a backrest* | *Sideward, leaning against a backrest* | *sideward facing* | *forward facing holding a grabpole* | *forward facing*

- Surface markers on head, hip, ankles
- Video recording @250 fps
- Tracking of markers provides their trajectories and velocities
- Questionnaires filled by the subjects (to evaluate their filling of desequilibrium…)

Standing occupants kinematics: *results*

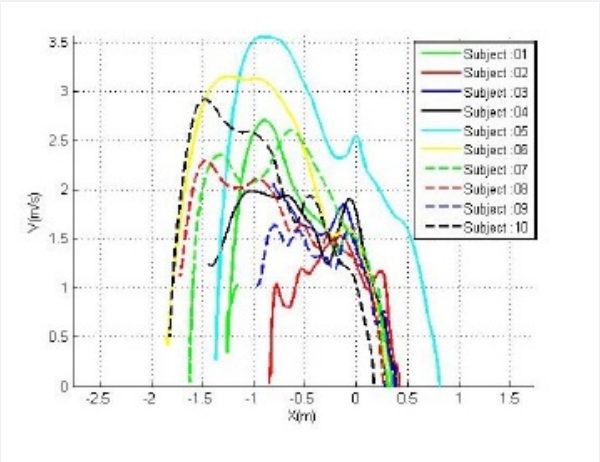
- Example



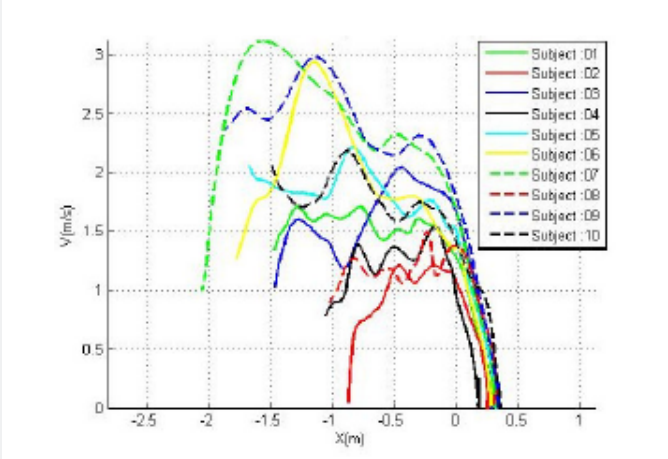


Standing occupants kinematics: *results*

- Example of head tangential velocities vs horizontal displacement



Rearward facing configuration



Forward facing configuration

	min	max
Head velocity (m/s)	0.45	3.6
Excursion (m)	0.3	2.38

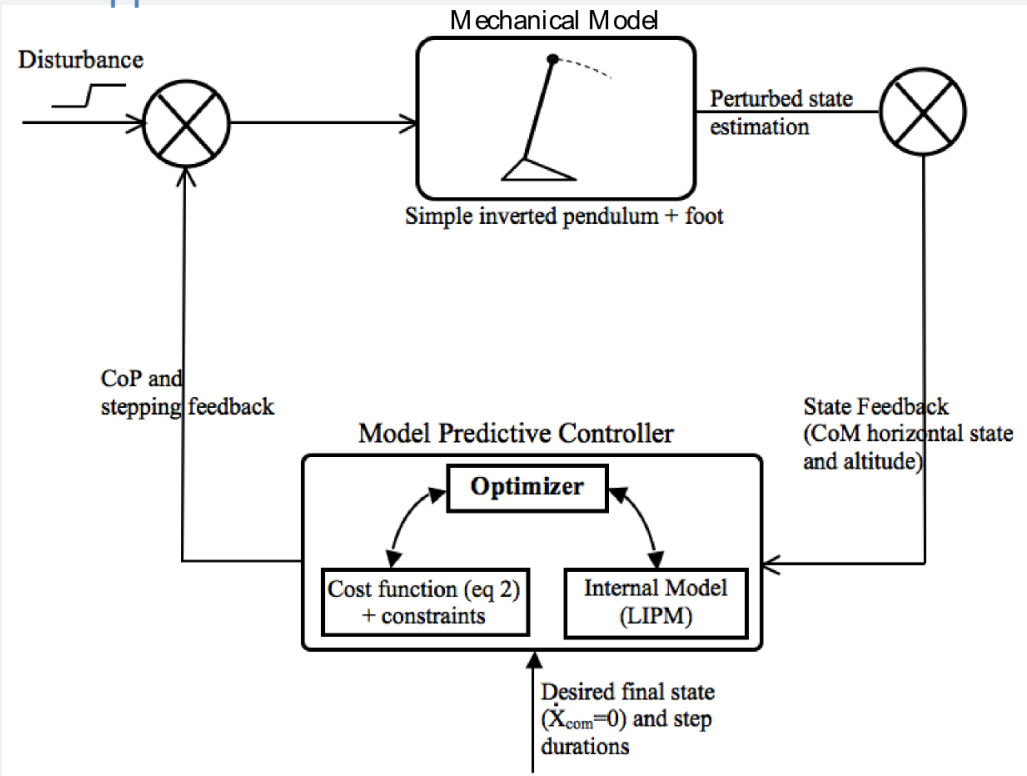
Standing occupants kinematics: *results*

- Kinematics trends:
  - Subjects forced to perform steps to preserve their balance
  - Different strategies
    - some subjects prepare themselves before the pulse and make steps to resist the forced motion.
    - others try to keep their torso upright without resisting and finish their course in the foam mattress
    - crossing the legs / making “chassé” lateral steps (sideward facing)
  - Influence of the direction
    - Rearward facing configuration is the most critical
      - all the subjects finish their course in the mattress
    - Sideward facing situation is also critical for some subjects
    - Forward facing situation is easier to control for subjects
  - Duration of the pulse seems to have a great effect on balance recovery
  - Use of a buttock rest increases the stability (even in the sideward direction)
  - Use of a grab pole provides a good restraint effect and limits the excursion of the body

Toward the simulation of the balance recovery kinematics

PhD Zohaib Aftab

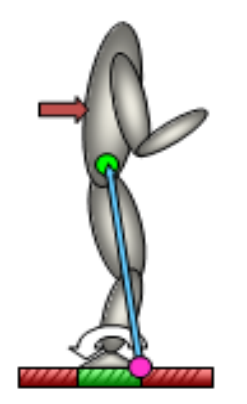
- Principle
  - A human body representation is placed in a close loop with a controller
  - At each time-step, the best control actions that will zero the CoM velocity is decided and applied.

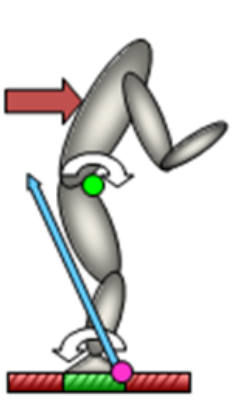


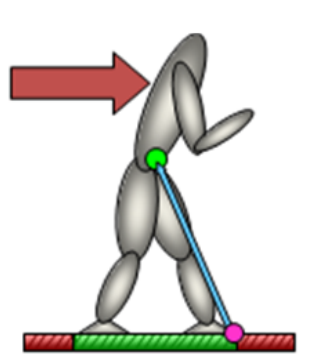
Toward the simulation of the balance recovery kinematics

PhD Zohaib Aftab

- Principle
- Control actions
  - Moving the center of pressure
  - Rotating the upper body
  - Making a step



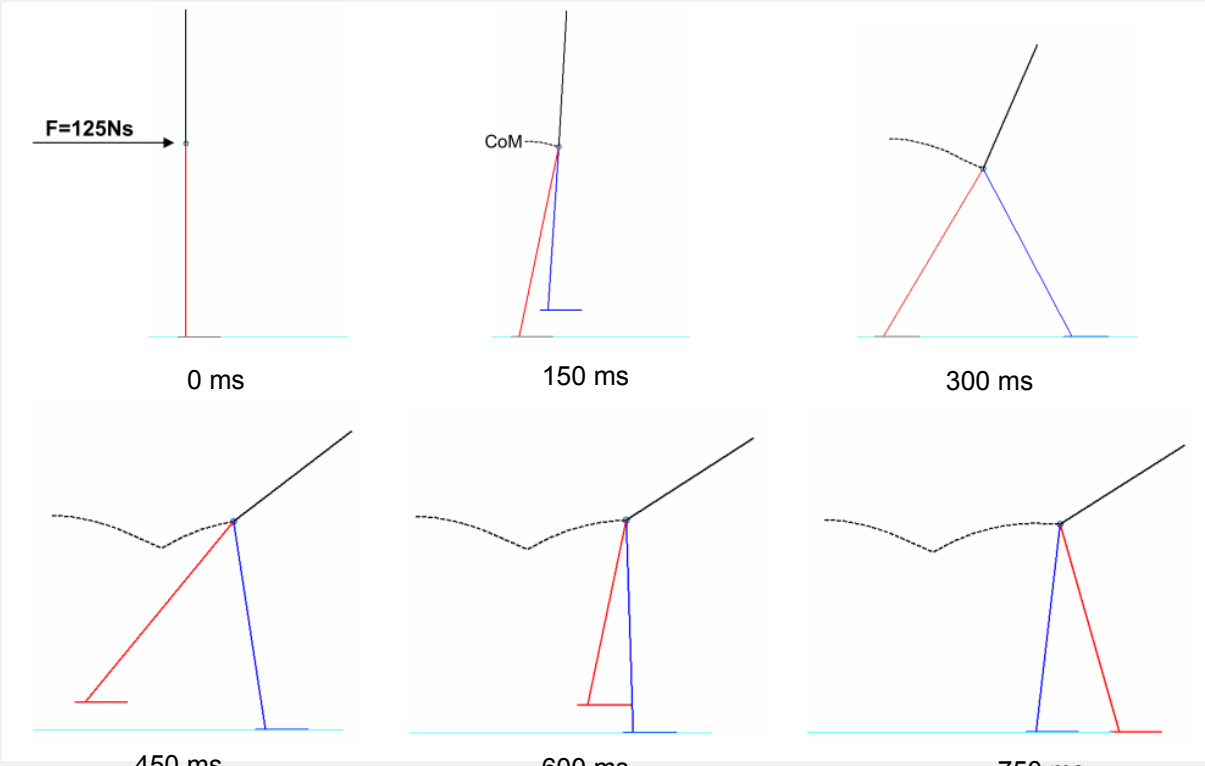




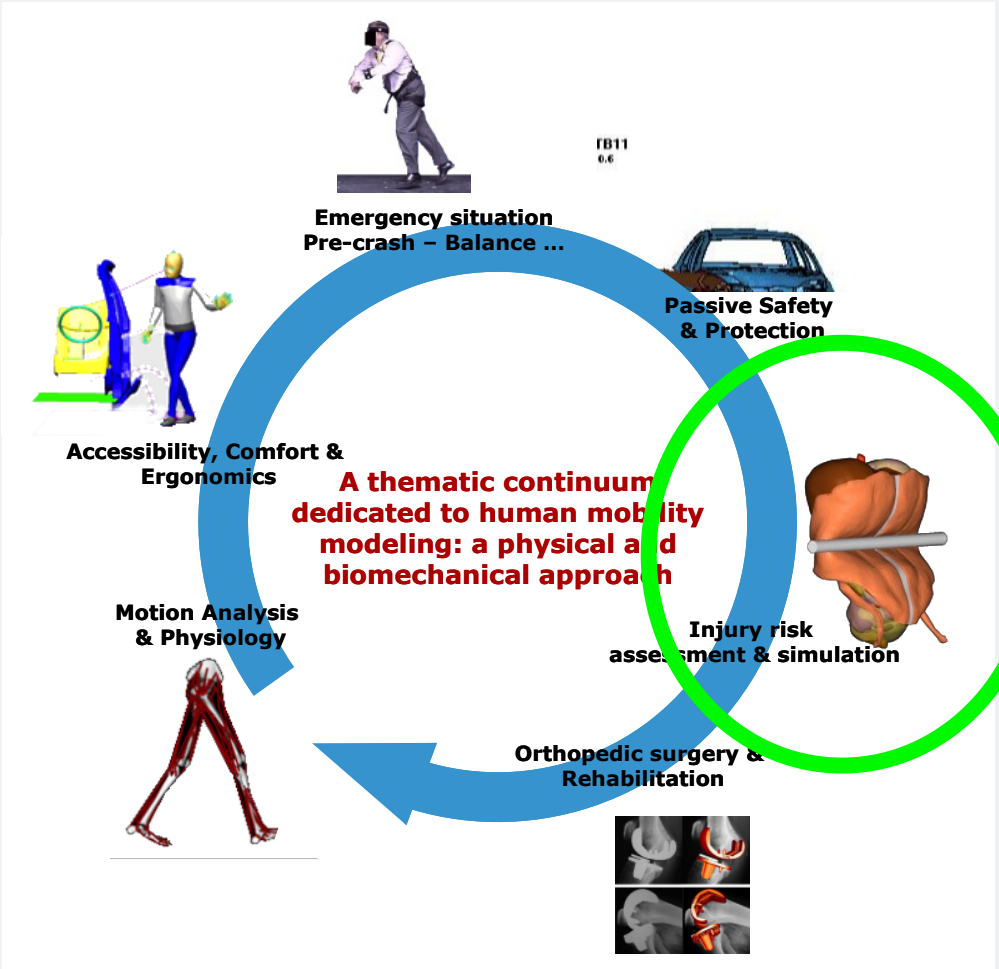
Toward the simulation of the balance recovery kinematics

PhD Zohaib Aftab

- Principle
- Control actions
- Example of results



Evaluation of Head Injury Risk



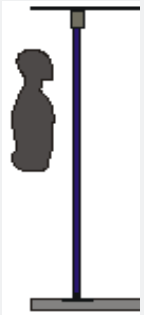
Evaluation of Head Injury Risk

What is the risk of head injury when impacting a grabpole during a crash or an emergency braking?

- Statistics identify the head as the most exposed part of the body
- Grab poles are the most common furniture in standing areas

Evaluation of Head Injury Risk: *methods*

- Head impact initial conditions

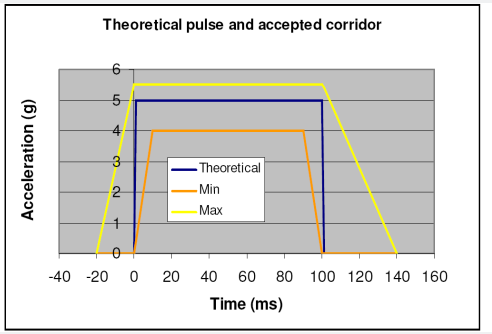


REFERENCE SCENARIO

« What is the most common way to impact a grabpole? »

– Passenger standing 25 to 50cm from a pole
– Lack of reaction prior to impact with a grabpole

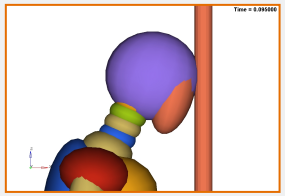
Crash Pulse

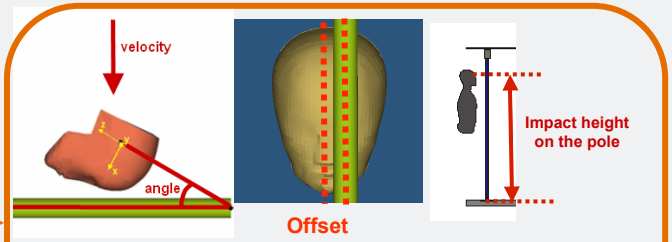


SAFEINTERIOS BACKGROUND

Reference scenario

Multi-body simulations

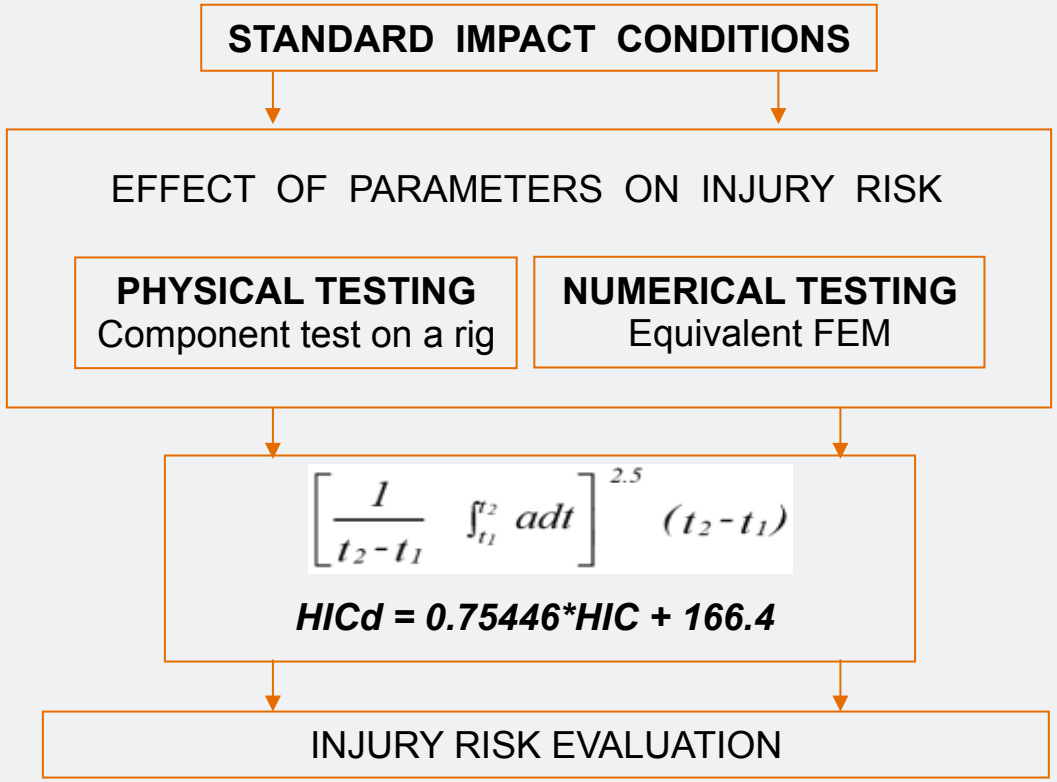




STANDARD IMPACT CONDITIONS

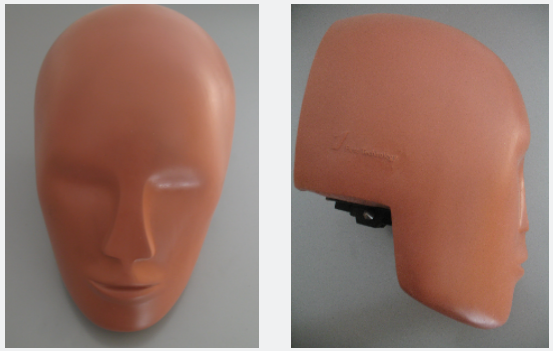
Impact velocity: 5.23m/s
Head angle: 24.5°
Impact height: 1.75m
Head Offset: 0

Evaluation of Head Injury Risk: *methods*



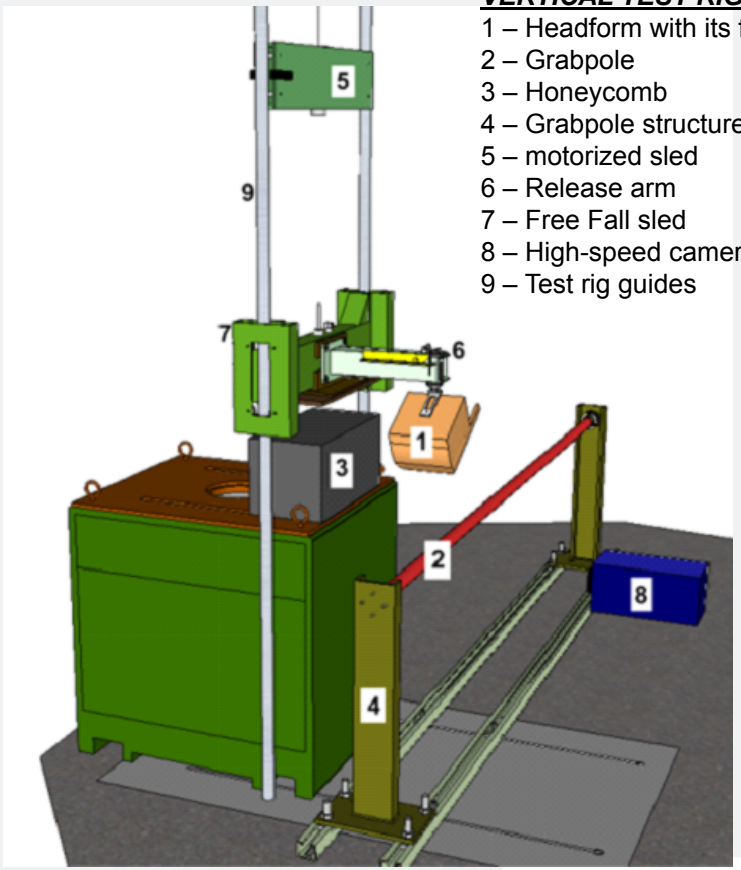
Evaluation of Head Injury Risk: *methods*

PHYSICAL TESTING



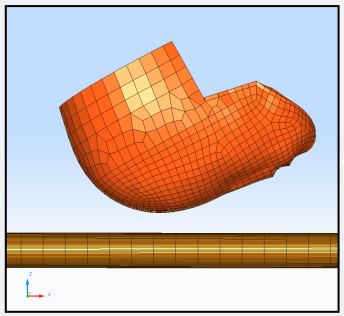
EVALUATION TOOL: FMVSS201 HEADFORM
Hybrid III headform without nose
Assessing interiors in automotive industry

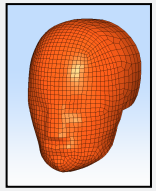
VERTICAL TEST RIG
1 – Headform with its fixings
2 – Grabpole
3 – Honeycomb
4 – Grabpole structure
5 – motorized sled
6 – Release arm
7 – Free Fall sled
8 – High-speed camera
9 – Test rig guides

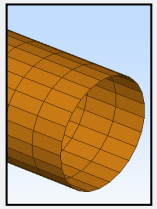


Evaluation of Head Injury Risk: *methods*

NUMERICAL TESTING



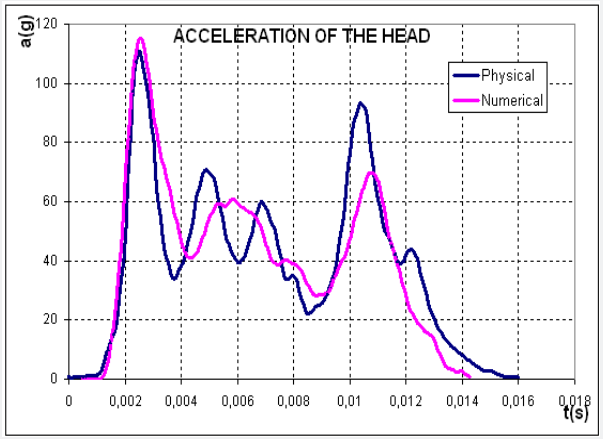




ALTAIR FREE MOTION HEADFORM
- Aluminum skull (Rigid Body)
- Hyperelastic foam skin (Law 42)

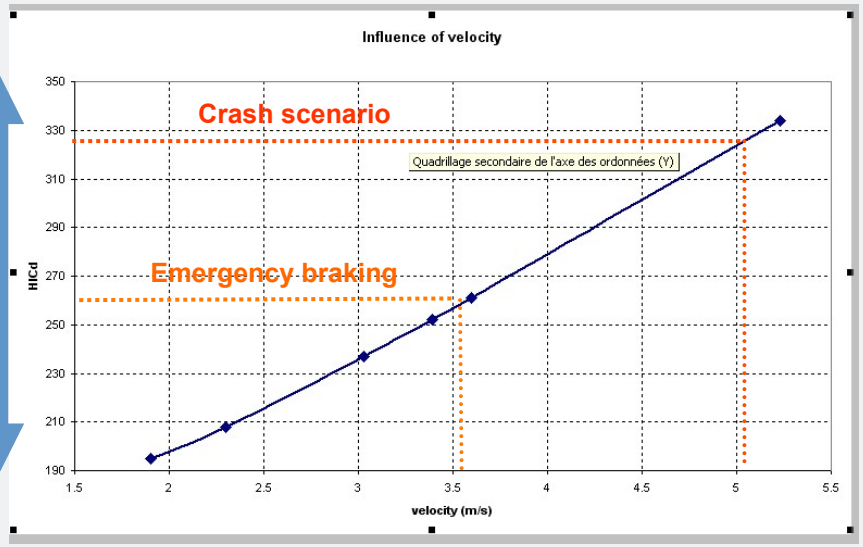
GRABPOLE FEM
- Shell elements (2D)
- Size: 2200 x 35mm (wall thickness: 2mm)
- Stainless steel 304 through Johnson-Cook Law

Validation through experimental results



Evaluation of Head Injury Risk: *results*

Moderate injury risk



GENERAL TREND

– Linear relation between HICd and impact velocity

– Values of HICd → moderate injury risk : 20% chance to sustain an AIS2+ injury

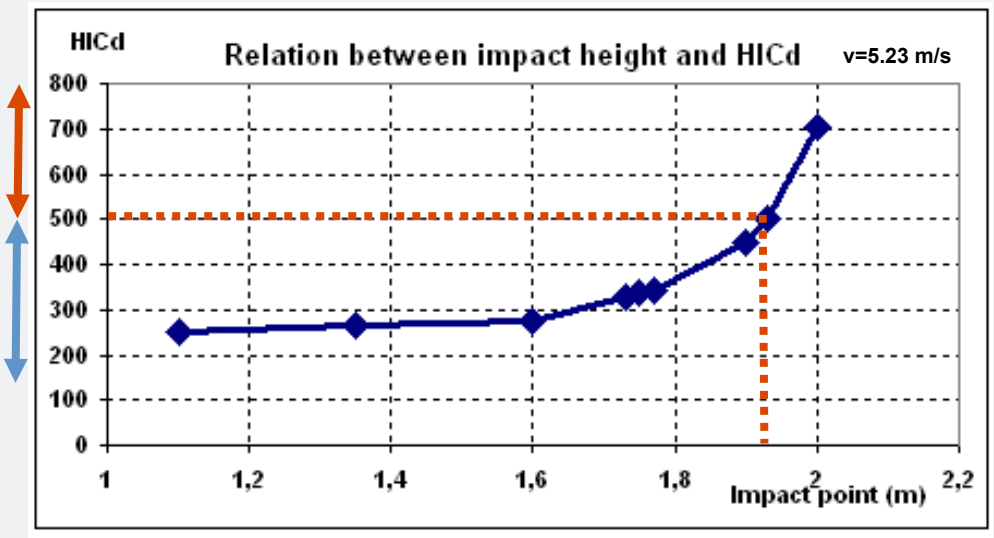
AIS = Abbreviated Injury Scale

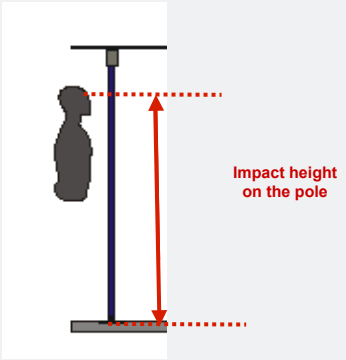
Evaluation of Head Injury Risk: *results*

- Strong effect of the impact height

Serious injury risk

Moderate injury risk





Tall passengers are more at risk: 20% chance to sustain an AIS3+ injury

Conclusion & Perspectives

- Standing passengers submitted to an emergency braking
  - Analysis of volunteers kinematics shows that subjects achieve different performance levels
  - Rearward facing configuration is demonstrated to be the most critical situation
  - Use of grabpole or buttock rest allows to reduce the excursion on the platform
  - Head velocity may reach up to 3.6 m/s
    - could be higher for elderly passengers due to large modification of reaction time, joint mobility and muscular power
    - May induce moderate injuries when head impacts a grab pole

Conclusion & Perspectives

- Standing passengers submitted to a crash deceleration
  - Lack of reaction (duration of the pulse is too short)
  - Case of head impact against a grab pole
    - Injury evaluation with a simple and repeatable methodology
    - Moderate injury risk
      - However some populations are more at risk
        - » Tall passengers: risks are much higher when impact takes place where the grabpole is the most rigid (close to its fixings)
        - » Elderly passengers
    - Need to still reduce injury risk to allow the full evacuation of the vehicle after a crash.
    - Limitations
      - no fully adapted criteria: HICd takes into account only linear accelerations
      - only one kind of population
  - Another scenarios could be investigated
    - Impacts against a rigid structure of the vehicle, falls , …

Thank you

Any questions?

This work has been developed in the framework of the European funded project SAFEINTERIORS (2006-2010), contract nº FP6-031260, with the partners UNewcastle, Alstom, ATOC, BT, CIDAUT, DB, INRETS, IST, MIRA, RSSB, Siemens, SNCF, UNIFE and VUKV.

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