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TRB

Accidents Involving E-scooters in Urban Areas: Typical Scenarios and Injuries and Protection Devices Assessment

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Context

e-scooters …

→ **Rapid growth of e-scooter practice in recent years**

→ 100% increase in the US 2019 VS. 2018[2];
→ + 200 million trips recorded by the rental company Lime

→ **A high risk of injury**

- 112 injured per millions of kilometers (167 times more than for cars) [1]
- 16% of all traffic injuries in the city of Lyon (France) in 2019 [2]

→ 40% rise in ES injury numbers in France (2020 vs 2019)[3]

→ **Specific protection devices**

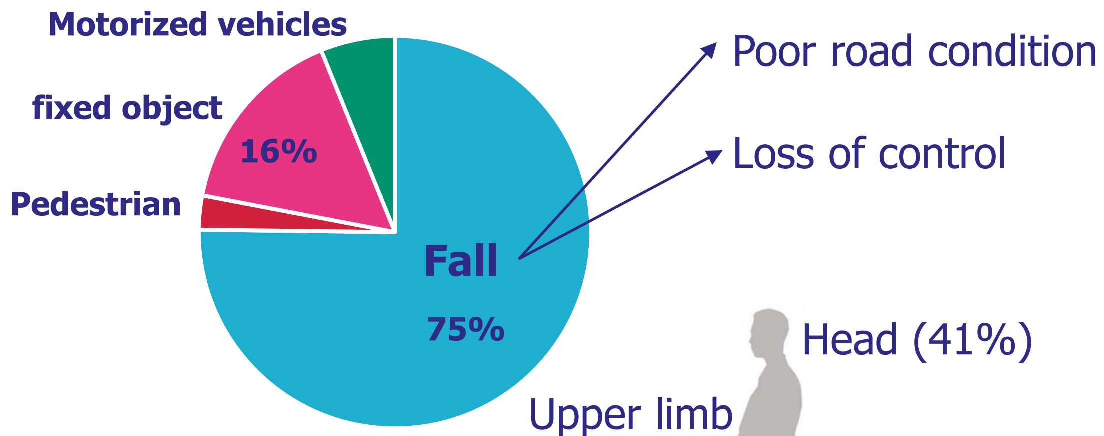
- No specific standard evaluation for e-scooter helmets

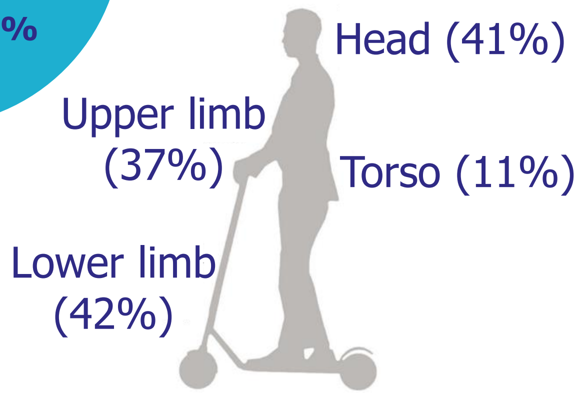
→ To properly evaluate the helmet
= need to be tested in realistic impact conditions!

→ **Very few knowledge on impact conditions and protection devices efficiency**

Context

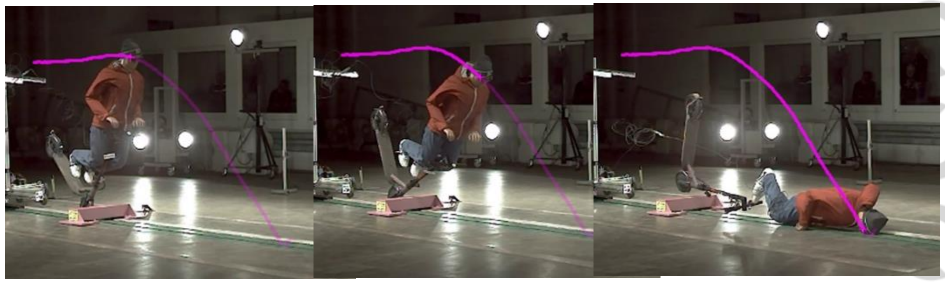
On field accident investigation + epidemiological studies

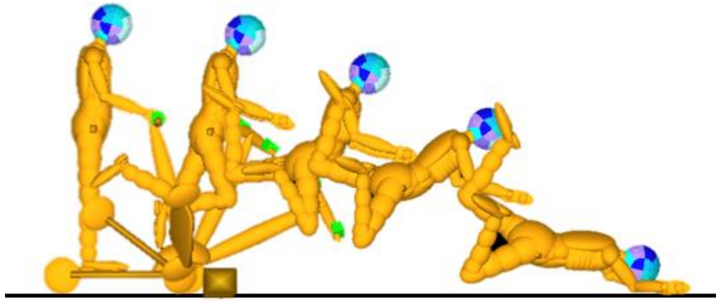




(Uluk 2021, English et al., 2020, Bekhit et al., 2020)

Experimental and numerical reconstruction





(Bailly et al. 2021, Fournier et al., 2022)

→ Overview of all accidents and injuries
→ Few details on accident mechanisms

→ Precise measurement of the impact velocity, location…
→ Question about biofidelity : No reflexes

Proposed Approach

→ **Use street cams video analysis**

Increasing number of cameras and quality of images

Qualitatively
to describe accident scenario

Quantitatively
to obtain impact conditions

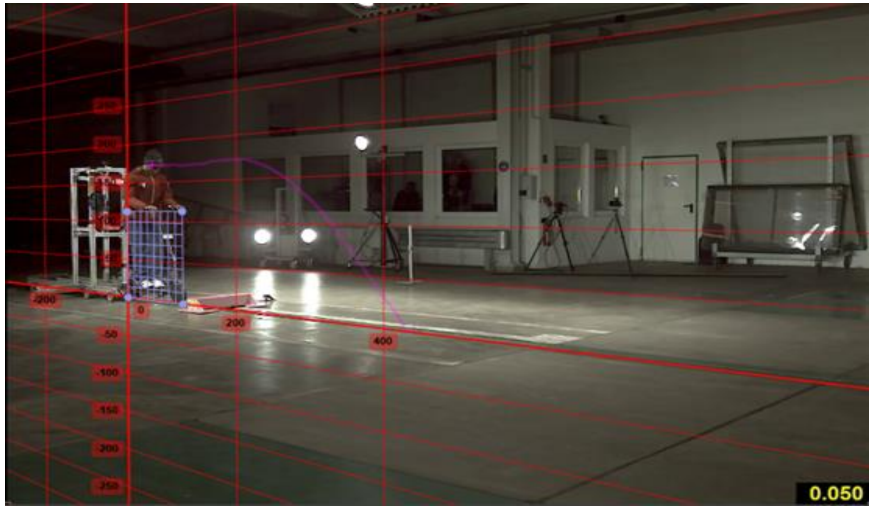
Objectives :

→ **Evaluate the feasibility of using video analysis to obtain head impact speed**

→ **Analyze a set of E-scooter crash videos found on the internet to obtain accident description and head impact speed**

Video Analysis Methodology

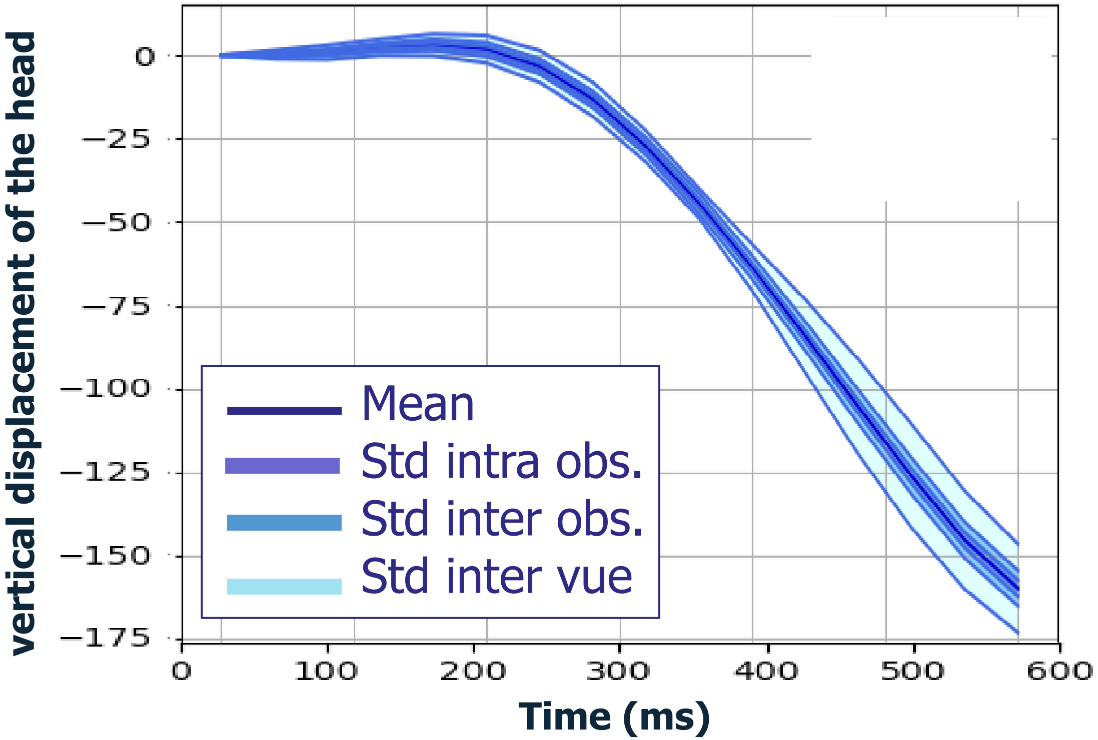
Validation of a tracking procedure : markerless MoCap with grid calibration (KINOVEA soft)



Scooter crash test with dummies (DEKRA)
≠ camera views

Calibration :
- Scooter dimensions
- Alignement of the grid with the direction of fall

Evaluation :
- Repeatability inter camera views
- The repeatability inter/intra observers (5 of each)



→ **Good agreement in results between camera views (<1.5% error) or observers**

Street cams Video Analysis

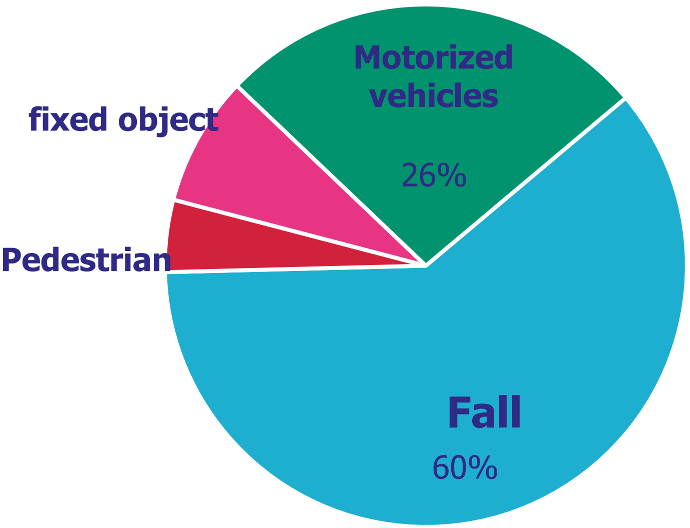
Systematic internet search to find E-scooter crash (YouTube and Google)

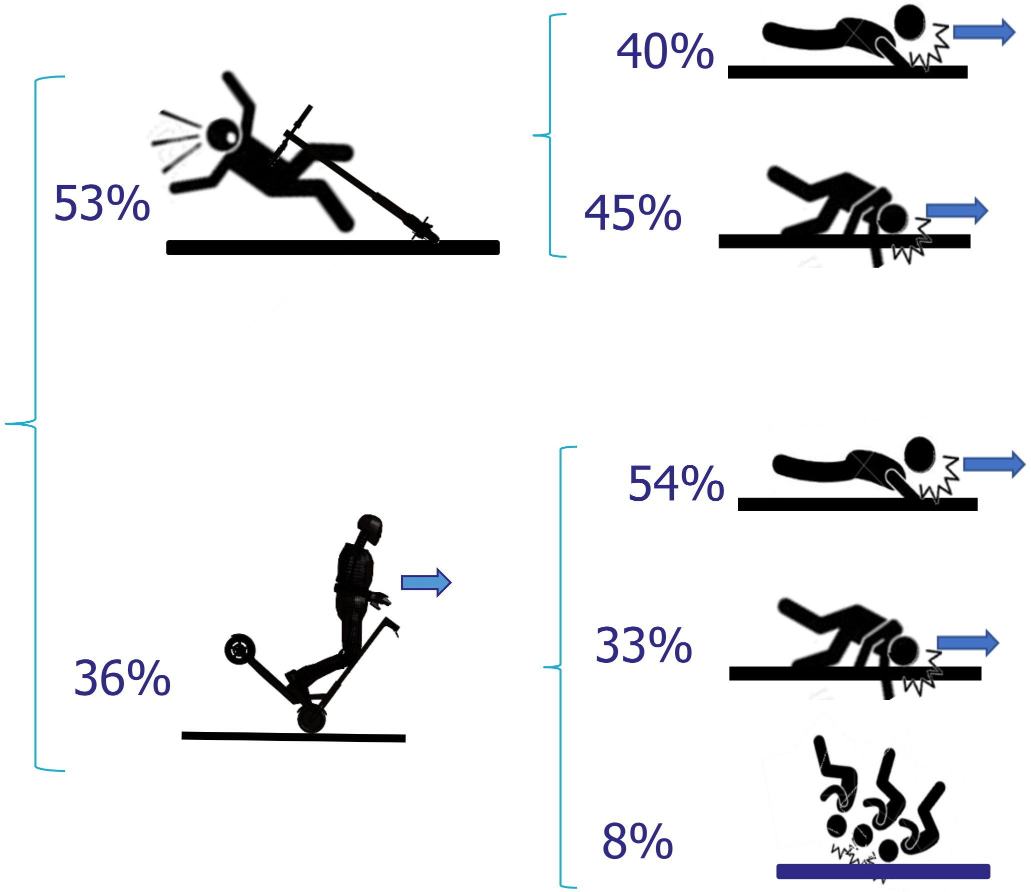
→ 120 crash videos : qualitatively describe the accident scenarios

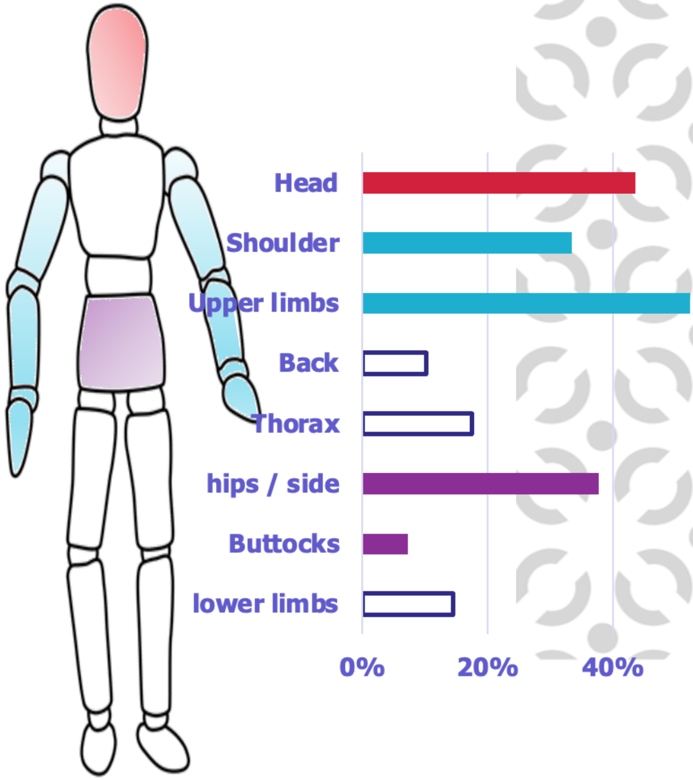
→ 12 falls videos : quantitative kinematic analysis of head impacts

Street cams Video Analysis

Qualitative analysis of 120 crash scenarios :







→ Mainly head first fall !

Street cams Video Analysis

Quantitative analysis of 12 specific cases : head impact speed measurement

→ Calibration based on E-scooter dimensions

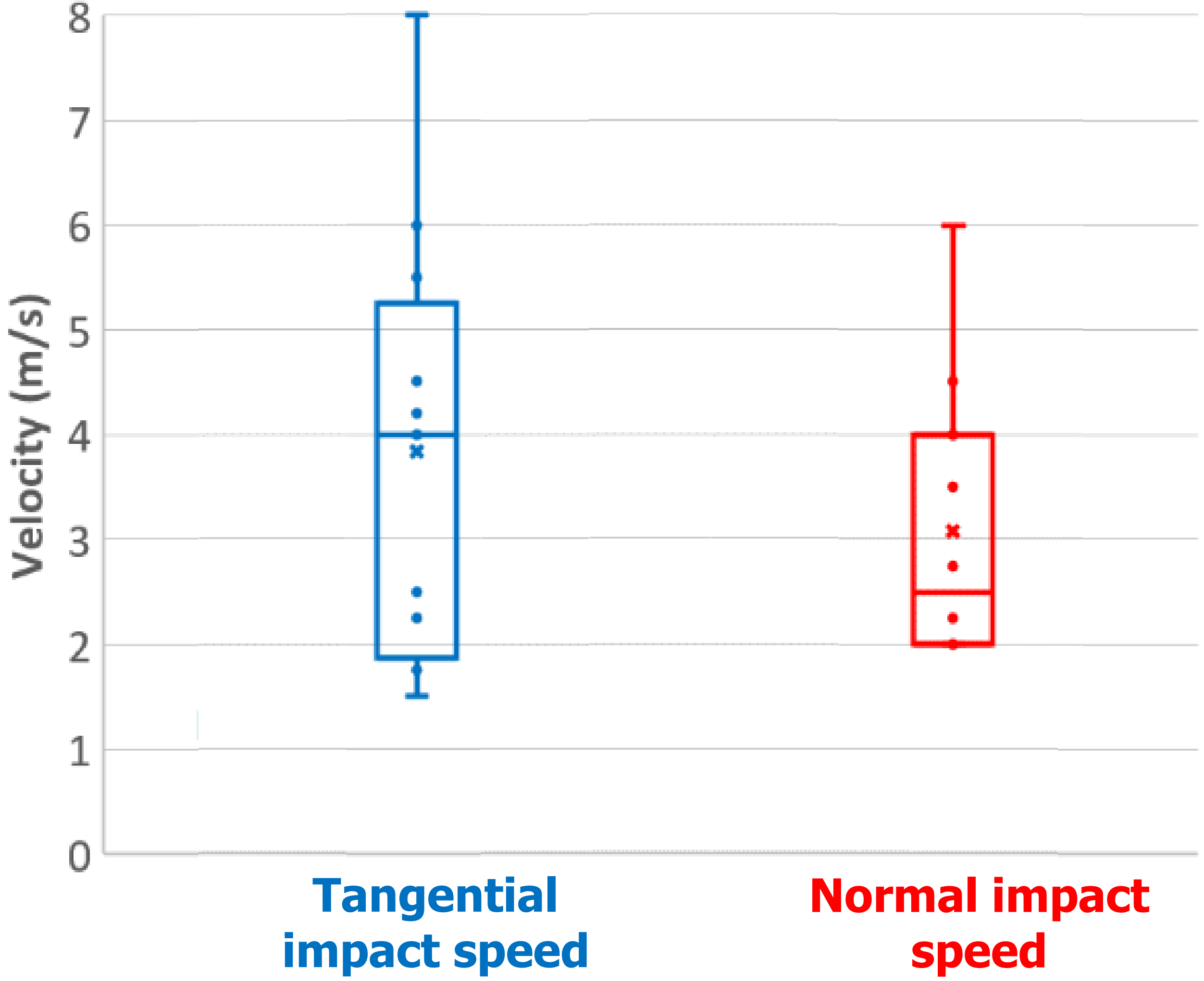
→ Tracking of head displacement

Tangential impact speed

Normal impact speed

Street cams Video Analysis - Results

Quantitative analysis of 12 specific cases : head impact speed measurement

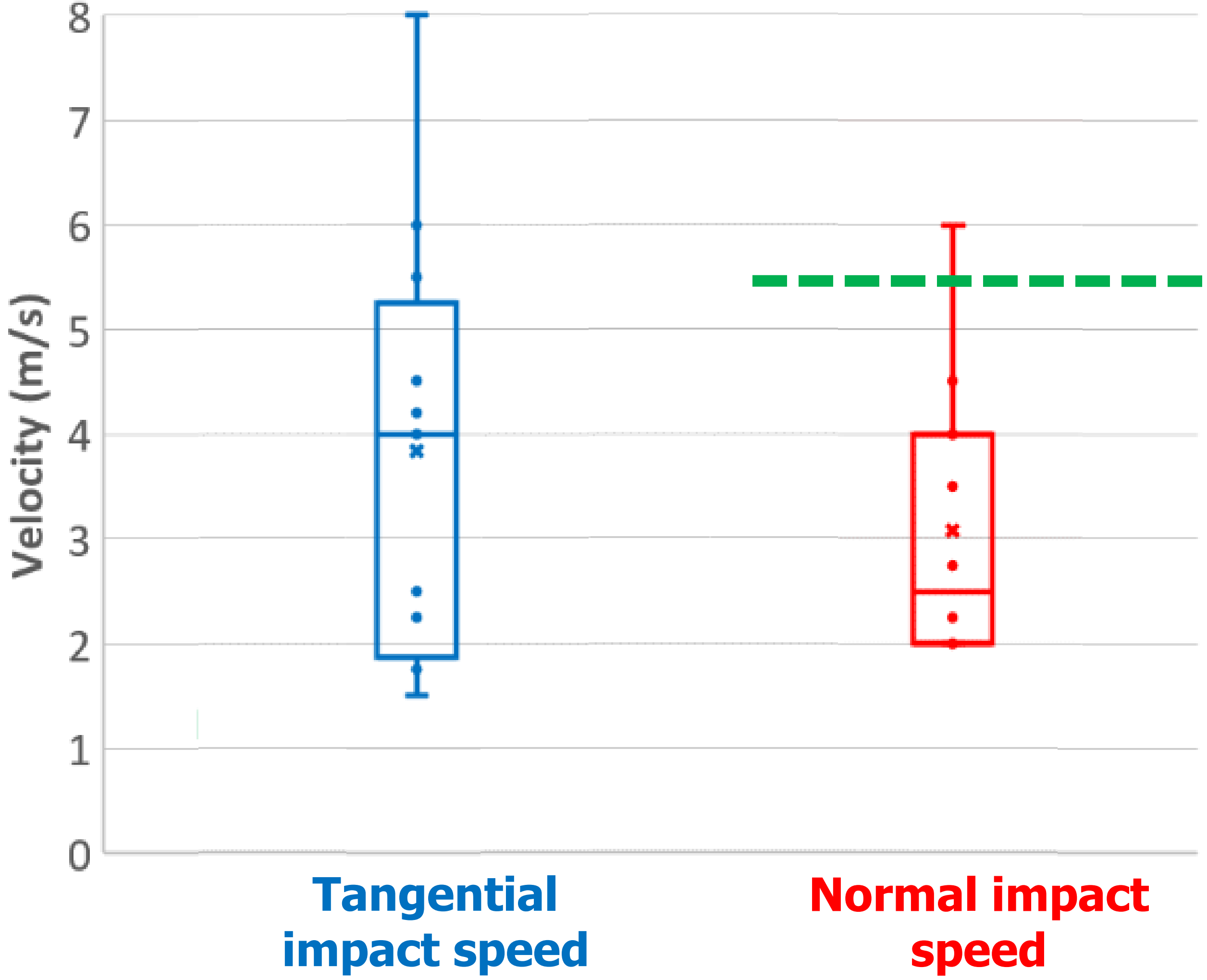


→ Large range of normal and tangential head impact speed

→ Tangential speed > normal speed

Results

Quantitative analysis of 12 specific cases



Standard evaluation

Impact speed in helmet standard test:

✓ Consistent with normal impact speed in worst-case scenario

✗ No tangential impact velocity (associated with rotational acceleration)

Protection devices evaluation

The ES FE model (A)

→CAD model: Xiaomi Mi Folding Electric Scooter M365;

→Dimension scale to the test ES dimensions

→Metal components modelled with typical steel: typical steel

→Tyres: 2.5bar airbag.

- **The rider FE model (B)**

→ The FE model of the hybrid III 50%tile male standing dummy;

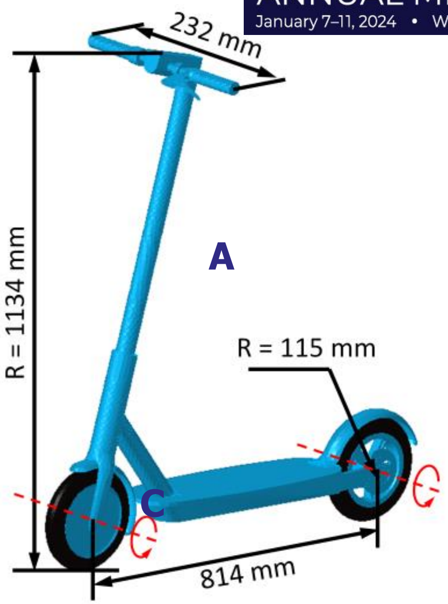
- **The bicycle helmet FE model (C)**

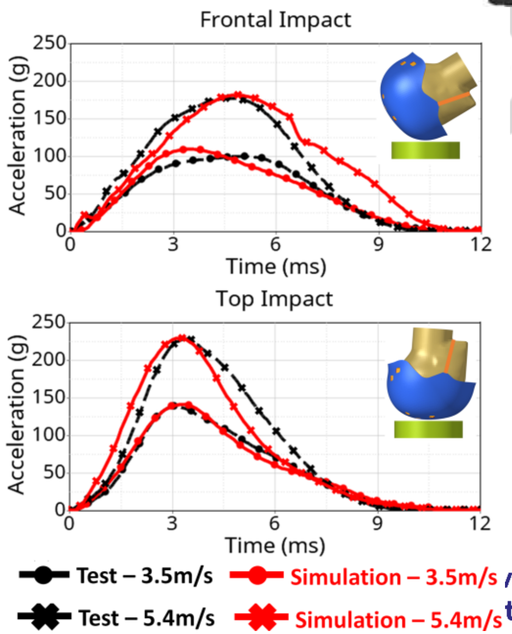
→ CAD model from previous study (Bailly et al., 2015); Bailly 2015

→ Outer shell + head strap: elastoplastic material, E=1000MPa, YS=70MPa

→ EPS liner: low-density foam material.

→ Validation against head form drop tests: 3.5m/s + 5.4m/s.





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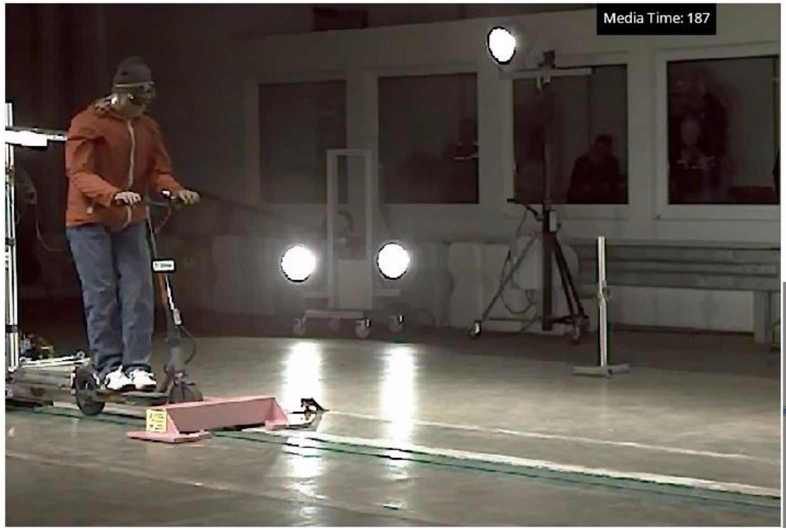
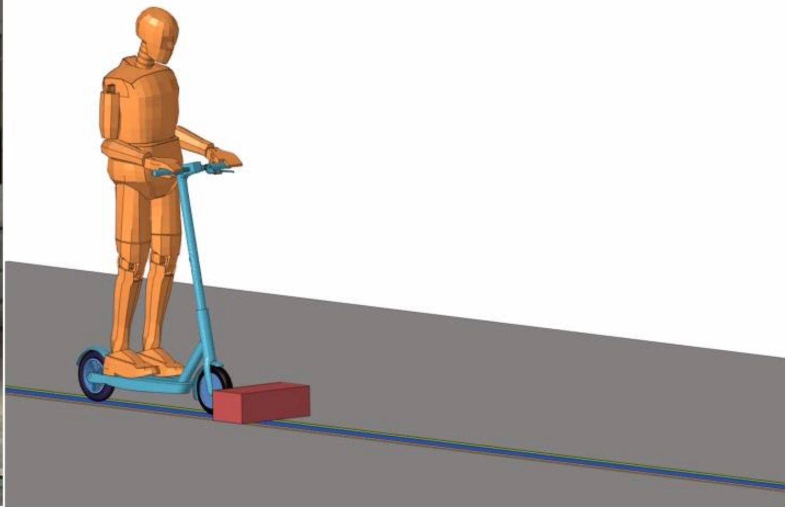
Protection devices evaluation

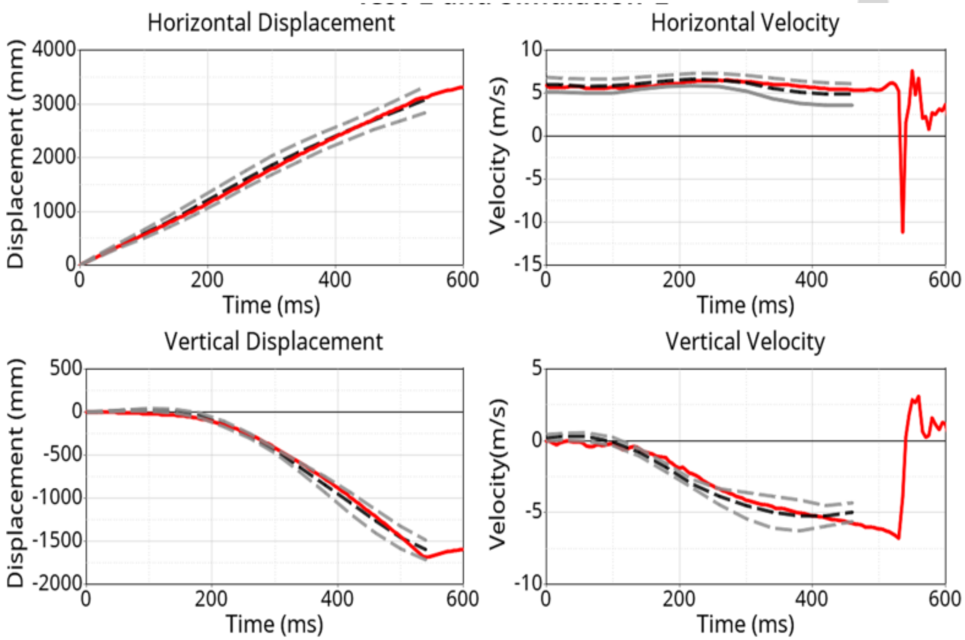
Validation of ES falls: qualitative validation in terms of body kinematics;

Test-1 (curb 90°)

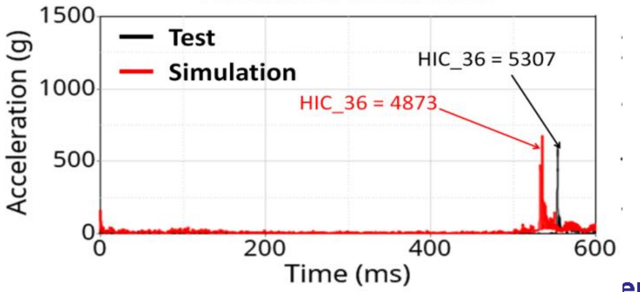


Simulation-1 (curb 90°)





Test-1 and Simulation-1

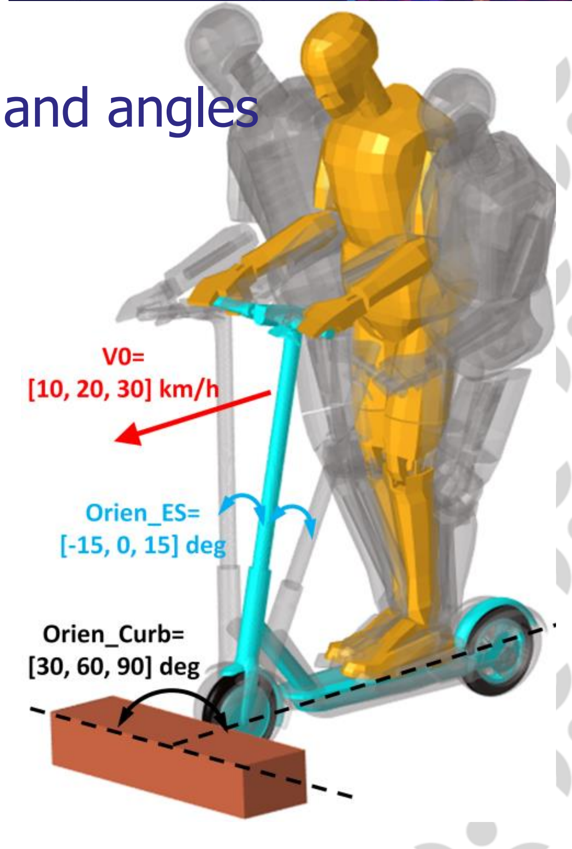


→ The FE model was able to predict head kinematics and head-ground impacts during ES falls.

Protection devices evaluation

Full DOE of 27 ES falls W/WO the helmet, at various riding speeds (10-30kph) and angles

→ Paired sampled T-tests on head kinematics and injury criteria (HIC36, BrIc)



- Linear acceleration (WO vs W): 328.5~1660.1g vs 126.2~ 1302.8g;
- HIC_36 (WO vs W): 1783.3~44136.5 vs 447.0~31114.1
- BrIC (WO vs W): 0.6~1.9 vs 0.5~1.8.

Significantly lower with the helmet ($p<0.01$)

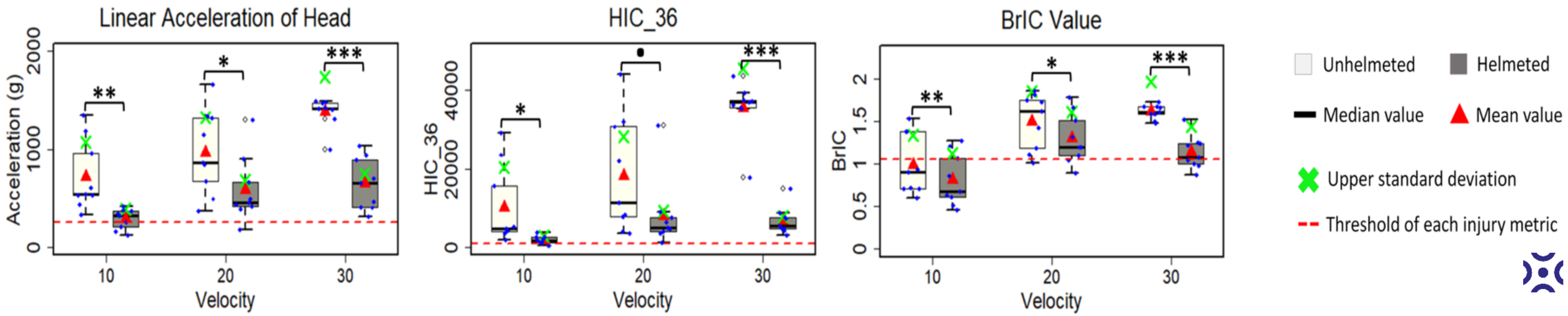
- Compared to the injury threshold:

  Linear acceleration (>250g for 50% AIS4+): 85.2%

  HIC_36 (>1000 for 50% AIS3+): 92.6%

  BrIC (>1.0582 for 50% AIS4+): 55.6%

A high risk of severe head injuries with the helmet



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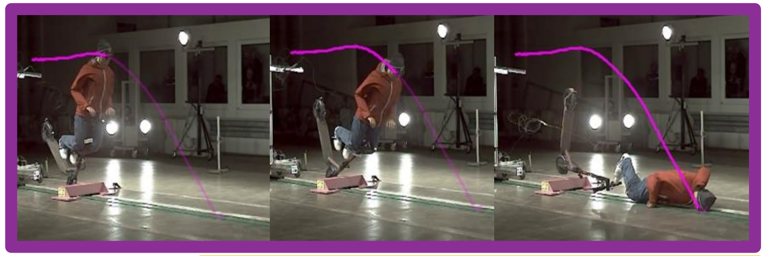
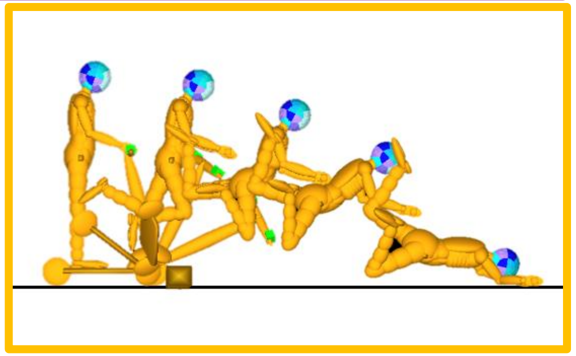
Conclusions

- Large range of normal and tangential impact speed (2 - 6 m/s)
- ES falls could result in severe head injuries:
  - → Oblique head-ground impacts with 5.7 m/s VN and 3.7 m/s VT.
- The bicycle helmet is efficient (but not enough?):
  - → Significantly reduces head injury metrics;
  - → Still higher than thresholds for severe head injuries (AIS3+)





Future work:

- Other head injury metrics: head angular acceleration and velocity, or brain tissue stress/ strain;
- Other head protections: motorcycle helmet, helmet airbag, etc;
- Other ES-related accident scenarios: ES-vehicle/ pedestrian/ obstacle crashes…

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Thank you!

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