Neck Protection Development
& a Proposal of the Associated Standard for the Motorcyclists'

Meeting for admission to the final exam

14th September, 2018 – CISAS (Padova)

Mohammed Nasim

ACKNOWLEDGMENT

The research leading to these results has received funding from the People Programme (Marie Curie Actions) of the European Union's Seventh Framework Programme FP7/2007-2013/ under REA grant agreement n° 608092 for the project MOTORIST.

MOTOR-IST MOTOrcycle Rider Integrated SafeTy

SEVENTH FRAMEWORK PROGRAMME

MARIE CURIE ACTIONS

DAINESE

UNIVERSITÀ DEGLI STUDI DI PADOVA

D| MOTORIST

MOTORIST Consortium

Partners

Università degli Studi Firenze

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SIEMENS

DAINESE

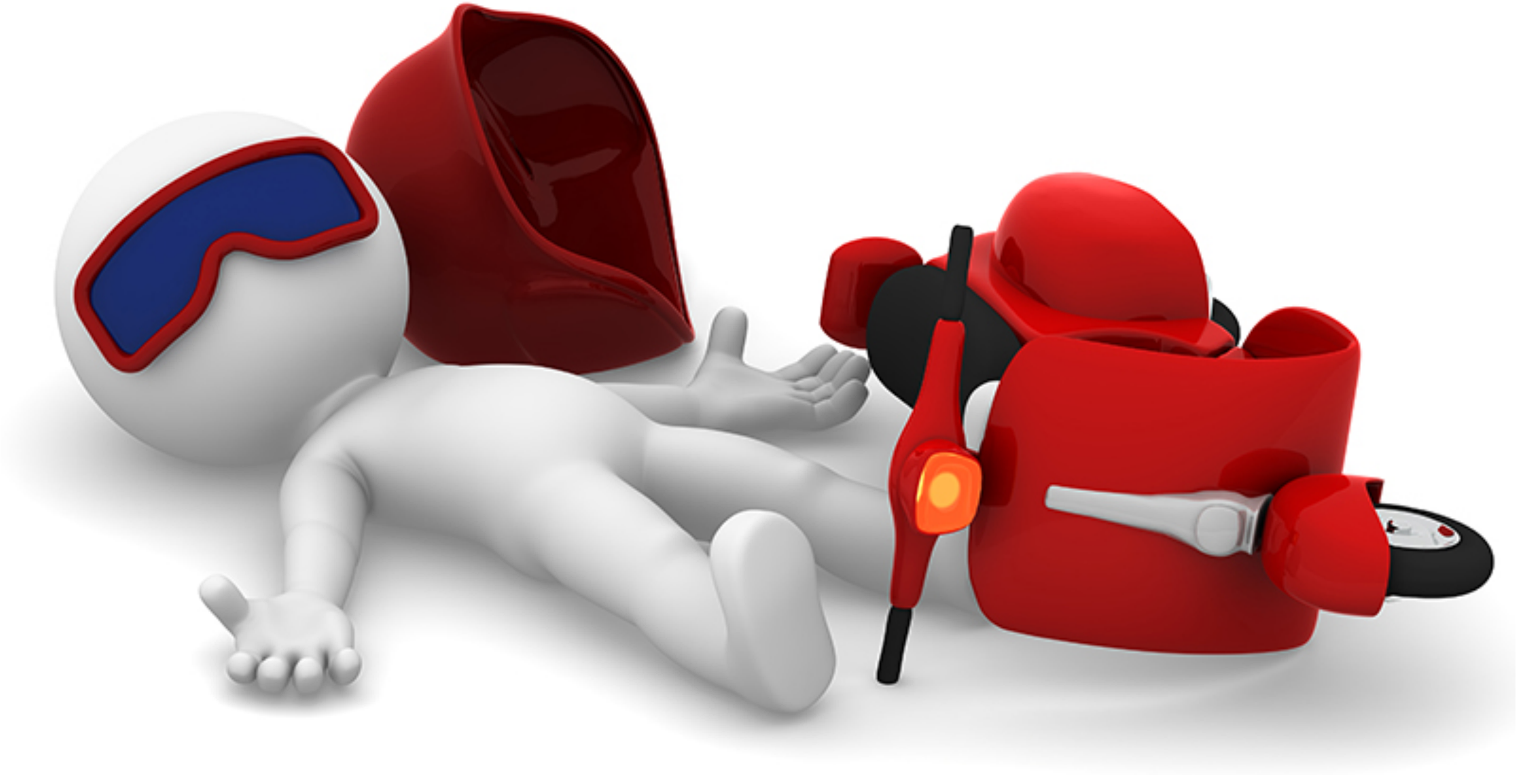
http://www.motorist-ptw.eu

Work Plan of ESR 3.3

MOTORIST Annex

Phase I: training on existing PPE		Phase II: design and develop new PPE	
Testing the state of the art	**New test methods**	**Functional requirements**	**Design and develop new PPE**
Review state of the art	Review injury biomechanics	Review phase I	Design / CAD
Review current technical standards	Technical standards vs injury biomechanics	Review accident statistics	Simulation (FEA)
Materials tests (physical, simulated)	Design and validate new test methods	State of the art vs accident statistics	Prototyping
		Functional requirements specification	Test aginst current and novel test methods
Guideline for material choice in current PPE	Guideline for better test methods	Decide which body part to protect, how	**New PPE** **Functional Prototype**

IMPACT PROTECTION



- Standards
- Impact analysis

D| EXISTING STANDARDS

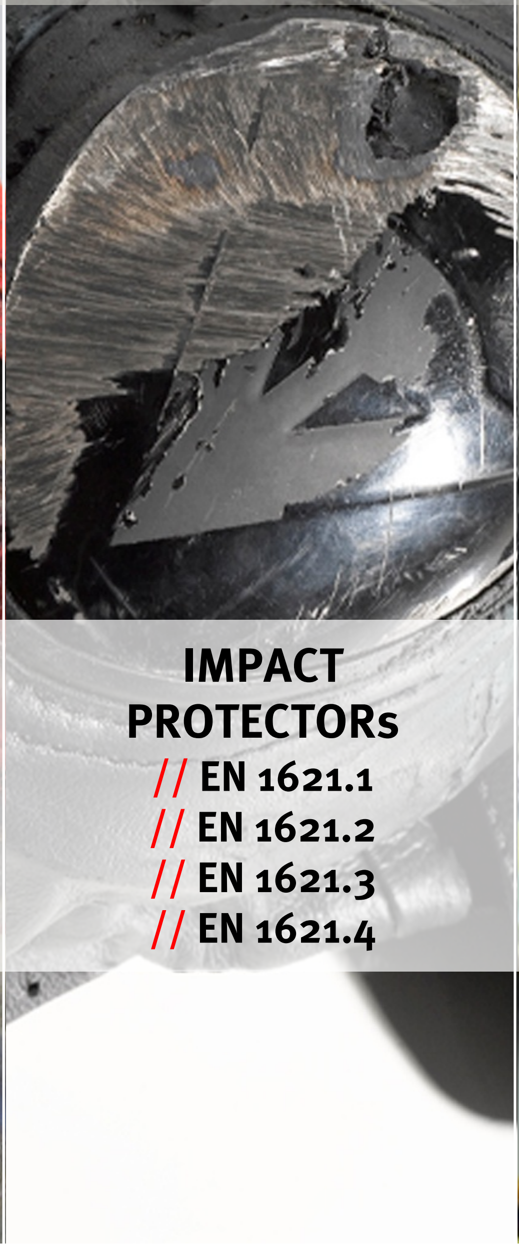
European Standards

Deliverable

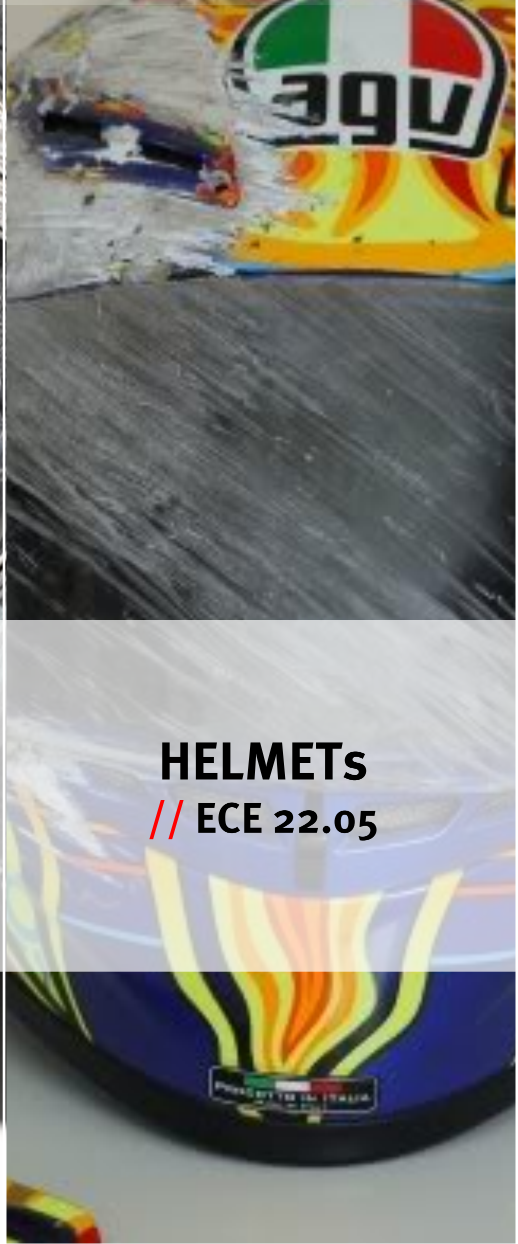
GARMENTs
// EN 13595
// prEN 17092

BOOTs
// EN 13634

GLOVEs
// EN 13594



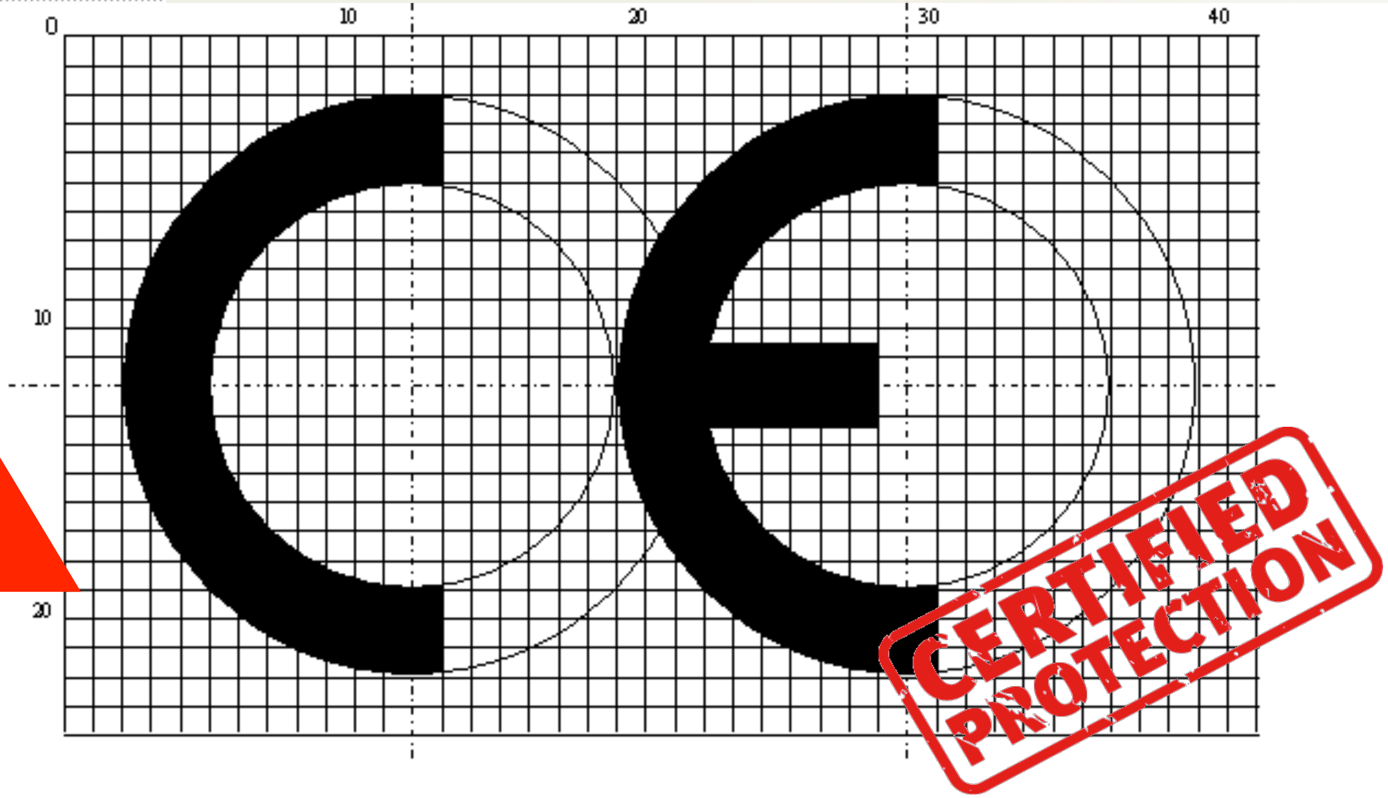
IMPACT PROTECTORs
// EN 1621.1
// EN 1621.2
// EN 1621.3
// EN 1621.4



HELMETs
// ECE 22.05

Standards

Deliverable



MOTOR-IST

MOTOrcycle Rider Integrated Safety

Deliverable no. 3.5

STANDARDS IN PPE, A SURVEY

Deliverable no.	D 3.5
Dissemination level	Public
Work Package	3
Author	Mohammad Nasim, Dainese
Co-authors	Michele Brasca, Dainese Alessandro Cernicchi, Mavet Enrico Silani, Dainese
Status (F: final, D: draft)	F
File Name	Standards in PPE, a survey
Project Start Date and Duration	February 1, 2014 - January 31, 2018

Deliverable 3.5: Standards in PPE, A Survey

http://www.motorist-ptw.eu

D| IMPACT ANALYSIS

Publication

Journal

- Hard shell effect
- Vent holes effect
- Temperature effect

Polymer Testing 61 (2017) 249–257

Contents lists available at ScienceDirect

Polymer Testing

journal homepage: www.elsevier.com/locate/polytest

ELSEVIER

POLYMER TESTING

Product Performance

Understanding the impact properties of polymeric sandwich structures used for motorcyclists' back protectors

CrossMark

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A R T I C L E I N F O

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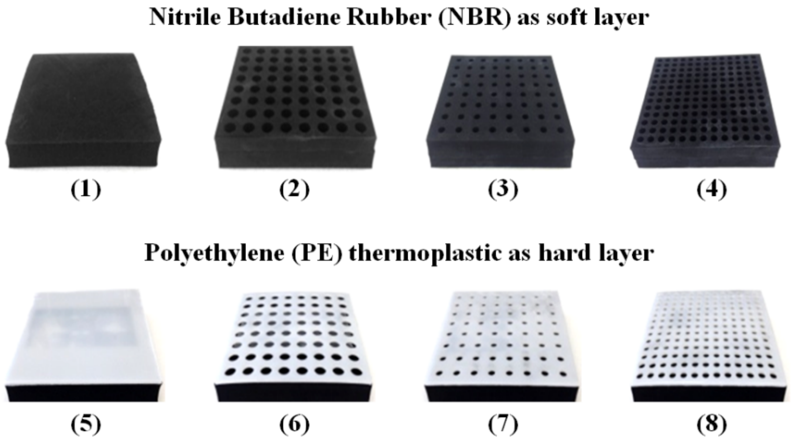
Polymer sandwich
Passive safety
Drop test
Personal protective equipment

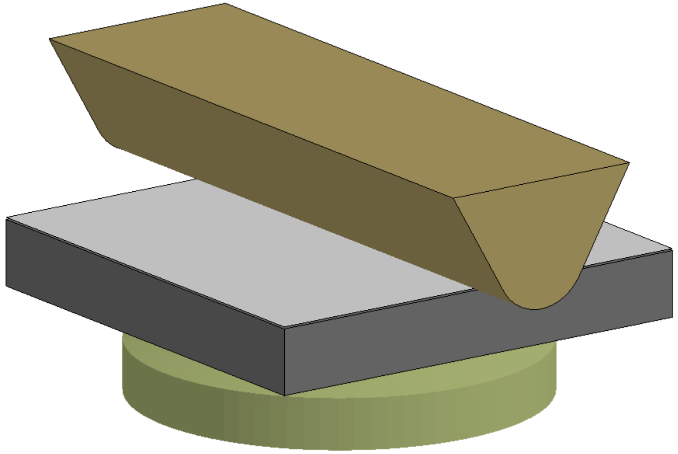
A B S T R A C T

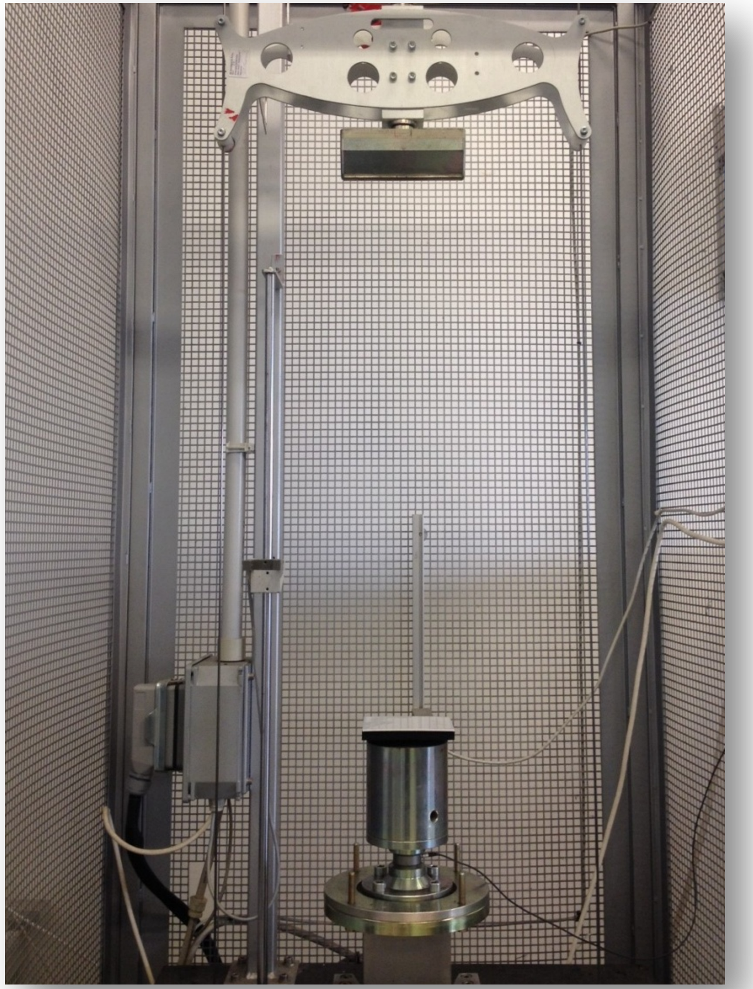
Conventional back protectors are comprised of two main parts: elastomeric foams to absorb the impact energy; and thermoplastic polymers to distribute the impact force on a wider area before the absorption process. Thermal comfort is usually maintained by vent holes within the structure. In the present work, the impact behavior of a number of samples made of materials commonly used for manufacturing such protectors was studied. Nitrile butadiene rubber as the soft layer and polyethylene thermoplastic as the hard layer were considered. The variables for the analyses were the thickness of the layers, the sample temperature and the distribution of the vent holes in the sample. The key findings are: the force distribution capability of the hard part and the stability of the impact properties with respect to temperature variations are fairly dependent on the thickness of the soft part; and a reasonable distance between two consecutive vent holes is required for achieving optimal impact protection.

Polymeric Sandwich Structures

Impact Properties

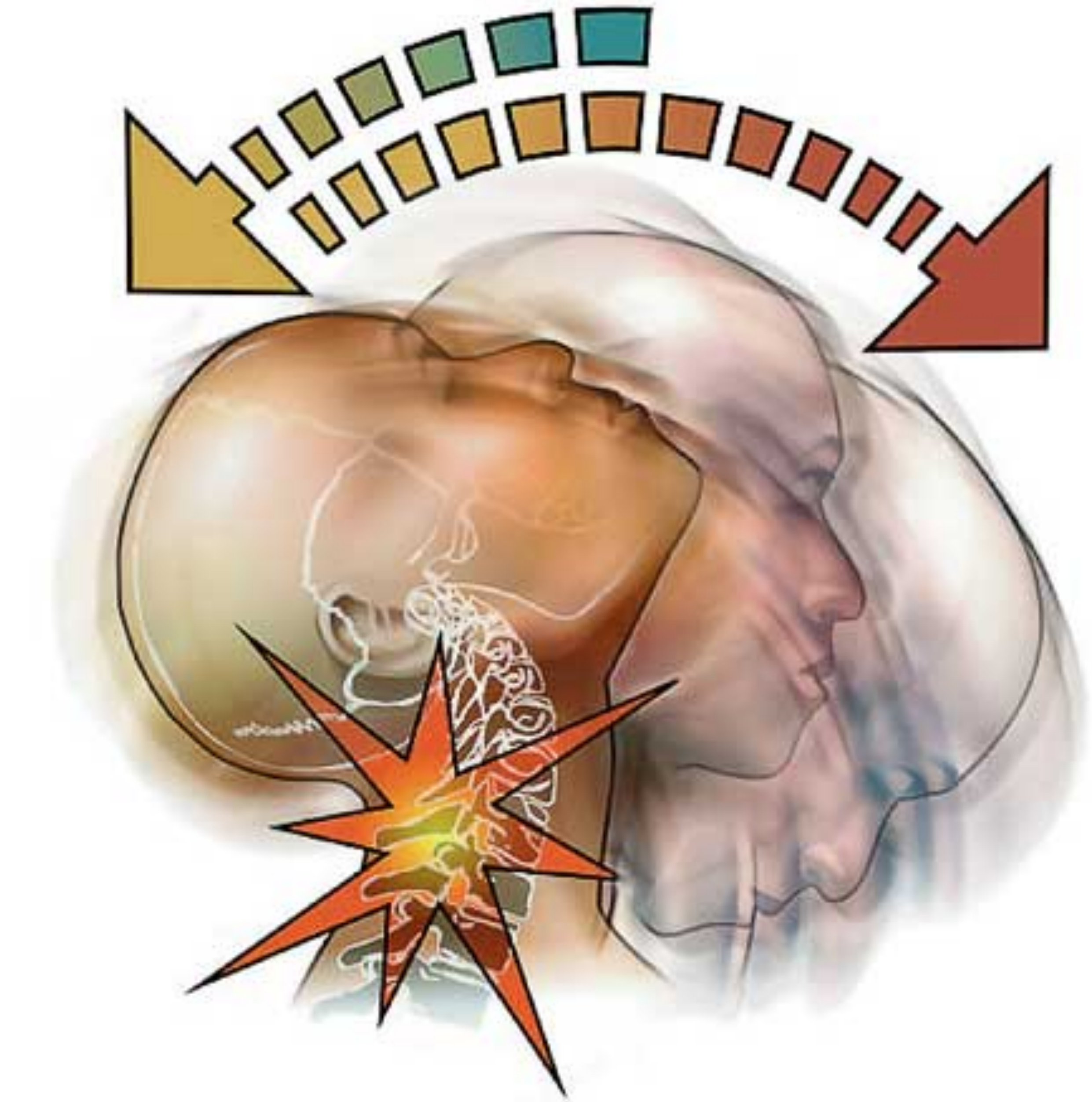






NECK INJURY PROTECTION

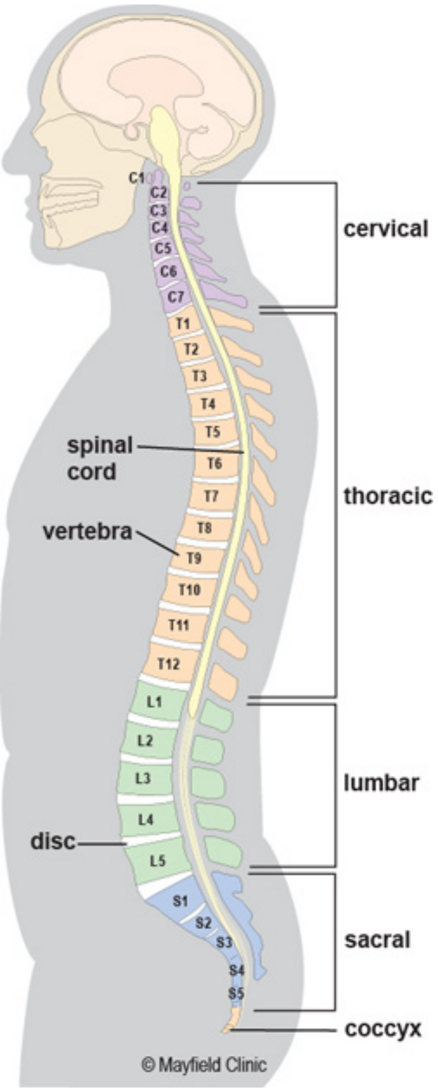
- Biomechanics
- Accident analysis
- Prototypes
- Evaluation
- D-neck
- Standards

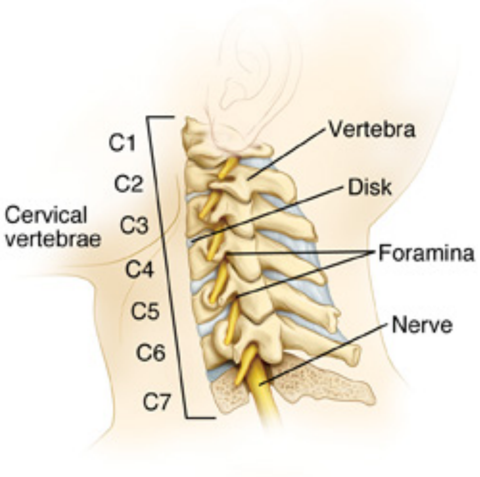


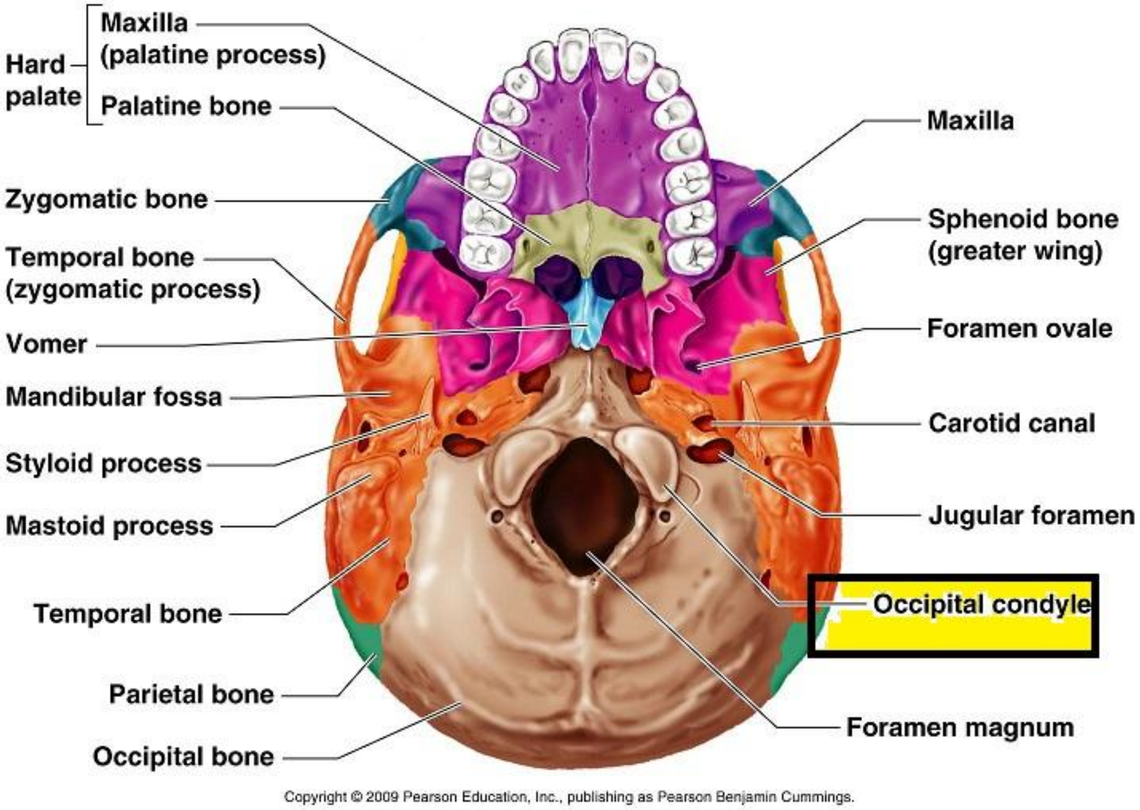
D| BIOMECHANICS

Cervical Spine & Lower Head

Biology of neck

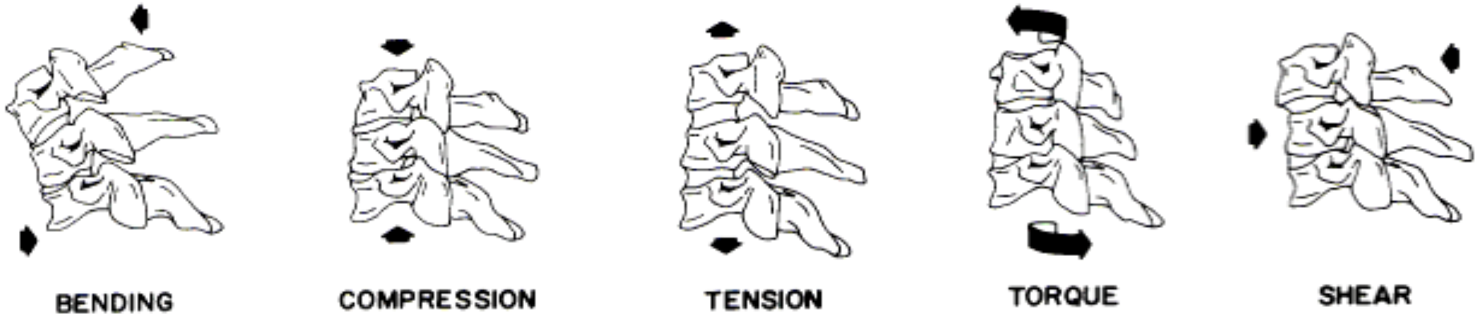


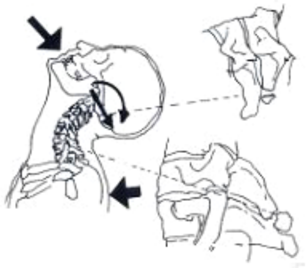




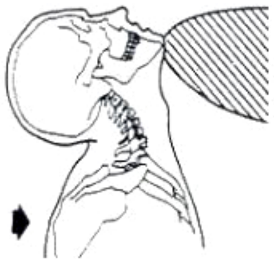
Loading Mechanism

Kinematics of neck

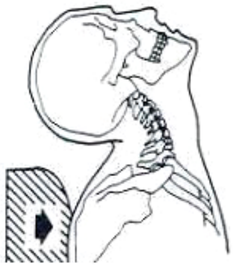




Head Extension with Tension



Head Axial Impact



Head Hypertension

Compression

Neck injuries

Classification

○ Compression injuries	○ Tension injury	○ Torsion injury
• Jefferson's fracture • comminuted fracture of atlas • compression fracture • burst fracture	• atlanto-occipital dislocation	• atlanto-axial dislocation
○ Compression and flexion	○ Tension and flexion injury	○ Shear injuries
anterior wedge fracture cervical sprain unilateral facet dislocation bilateral facet dislocation teardrop fracture	• bilateral facet dislocation	• atlanto-axial subluxation • odontiod fracture • Fracture of articular process?
○ Compression and extension	○ Tension and extension	○ Bending injuries
• Fracture of posterior element	Whiplash • tear of facet joint • tear of intervertebral disc • chip fracture • Hangman's fracture • teardrop fracture	• narrowing of intervertebral foramen • compression of articular process
○ Other injury		
• Clay-shoveler's fracture		

Injury Severity
Abbreviated injury scale

Examples of spinal injuries according to AIS scale

AIS code	description
1	skin, muscle: abrasion, contusion (hematoma), minor laceration
2	vertebral artery: minor laceration cervical/thoracic spine: dislocation without fracture thoracic/lumbar spine: disc herniation
3	vertebral artery: major laceration cervical/thoracic spine: multiple nerve root laceration
4	cervical/thoracic spine: spinal cord contusion incomplete
5	cervical/thoracic spine: spinal cord laceration without fracture
6	decapitation cervical spine: spinal cord laceration at C3 or higher with fracture

Association of Advancement of Automotive Medicine, 2004

D| ACCIDENT STATISTICS

Neck Injury & Head Impact Speed

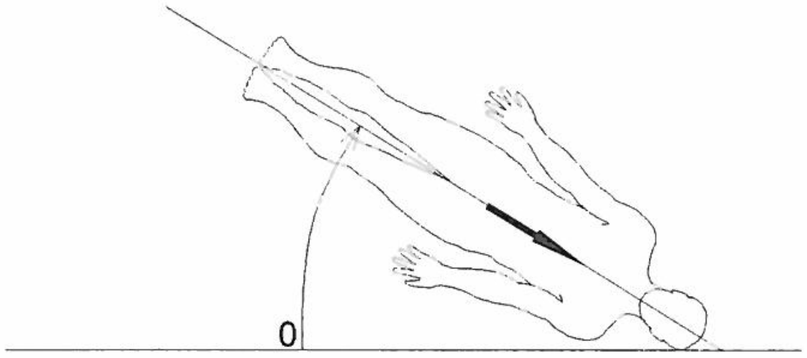
Accident analysis

Speed head impact [km/h]	total		injuries of the neck							
			cervical spine strain		cervical spine fracture		soft tissue injury		other	
	n	%	n	%	n	%	n	%	n	%
< 10	2	1.8	1	8.3	-	-	-	-	1	6.7
11 - 20	-	-	-	-	-	-	-	-	-	-
21 - 30	14	12.3	4	33.3	7	13.0	1	3.0	2	13.3
31 - 40	3	2.6	2	16.7	1	1.9	-	-	-	-
41 - 50	14	12.3	1	8.3	10	18.5	3	9.1	-	-
51 - 60	10	8.8	-	-	4	7.4	4	12.1	2	13.3
61 - 70	6	5.3	-	-	4	7.4	1	3.0	1	6.7
71 - 80	13	11.4	-	-	12	22.2	-	-	1	6.7
81 - 90	5	4.4	-	-	2	3.7	1	3.0	2	13.3
91 - 100	3	2.6	-	-	3	5.6	-	-	-	-
> 100	4	3.5	-	-	-	-	2	6.1	2	13.3
unknown	40	35.1	4	33.3	11	20.4	21	63.6	4	26.7
total	**114**	**100**	**12**	**100**	**54**	**100**	**33**	**100**	**15**	**100**

Source: COST database; Neck injuries in relation to head impact speed (100%=all neck injuries; 1 missing Speed head impact)

Body Impact Angle

Accident analysis

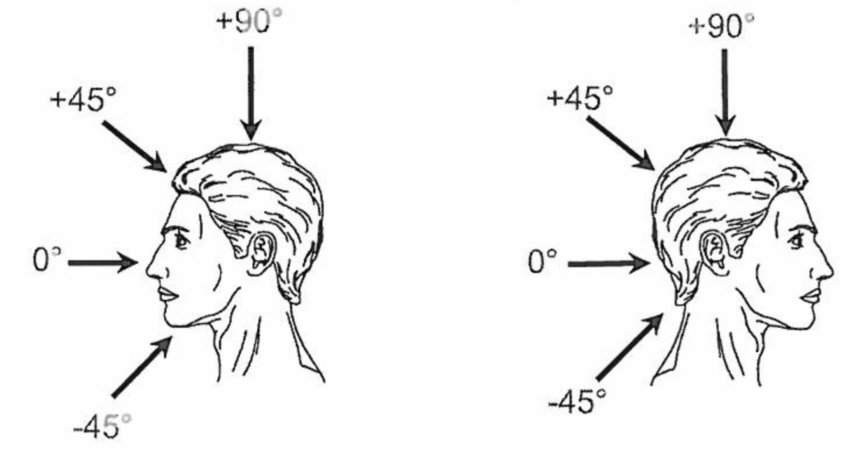


body impact angle [°]	total n	total %	cervical spine strain n	cervical spine strain %	cervical spine fracture n	cervical spine fracture %	soft tissue injury n	soft tissue injury %	other n	other %
			location of neck injuries							
< 15	35	30.7	4	33.3	20	37.0	3	9.1	8	53.3
16 - 30	12	10.5	3	25.0	-	-	9	27.3	-	-
31 - 45	3	2.6	-	-	2	3.7	1	3.0	-	-
46 - 60	9	7.9	-	-	4	7.4	5	15.2	-	-
> 60	29	25.4	1	8.3	22	40.7	2	6.1	4	26.7
unknown	26	22.8	4	33.3	6	11.1	13	39.4	3	20.0
total	**114**	**100**	**12**	**100**	**54**	**100**	**33**	**100**	**15**	**100**

Source: COST database; Body impact angle in relation to neck injury location (100%=each neck injury location; 1 missing body impact angle)

Head Impact Angle in Sagital Plane

Accident analysis

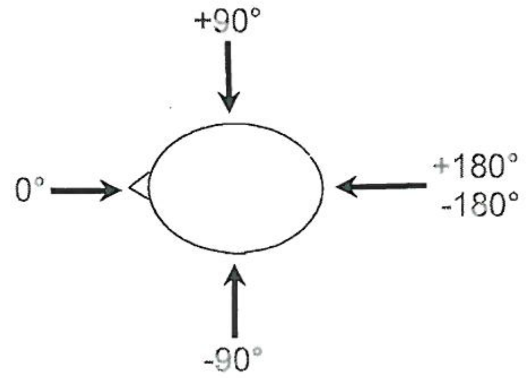


head impact angle ZX[°]	total		location of neck injuries: cervical spine strain		cervical spine fracture		soft tissue injury		other	
	n	%	n	%	n	%	n	%	n	%
0	52	45.6	2	16.7	34	63.0	6	18.2	10	66.7
1 - 45	14	12.3	4	33.3	2	3.7	6	18.2	2	13.3
46 - 90	3	2.6	-	-	3	5.6	-	-	-	-
91 -135	1	0.9	-	-	1	1.9	-	-	-	-
136 -180	5	4.4	-	-	3	5.6	2	6.1	-	-
unknown	39	34.2	6	50.0	11	20.4	19	57.6	3	20.0
total	**114**	**100**	**12**	**100**	**54**	**100**	**33**	**100**	**15**	**100**

Source: COST database; Head angle ZX in relation of neck injury location (100%=each neck injury location; 1 missing impact angle ZX)

Head Impact Angle in Transverse Plane

Accident analysis



head impact angle XY[°]	total		location of neck injuries: cervical spine distortion		cervical spine fracture		soft tissue injuries		other	
	n	%	n	%	n	%	n	%	n	%
0	17	14.9	2	16.7	6	11.1	5	15.2	4	26.7
1 - 45	16	14.0	-	-	8	14.8	7	21.2	1	6.7
46 - 90	7	6.1	1	8.3	5	9.3	-	-	1	6.7
136 -180	12	10.5	1	8.3	6	11.1	1	3.0	4	26.7
(-179)-(-135)	3	2.6	-	-	3	5.6	-	-	-	-
(-134)-(-90)	1	0.9	1	8.3	-	-	-	-	-	-
(-89)-(-45)	4	3.5	1	8.3	3	5.6	-	-	-	-
(-44) - (-1)	15	13.2	-	-	12	22.2	1	3.0	2	13.3
unknown	39	34.2	6	50.0	11	20.4	19	57.6	3	20.0
total	**114**	**100**	**12**	**100**	**54**	**100**	**33**	**100**	**15**	**100**

Source: COST database; Head angle XY in relation of neck injury location (100%=each neck injury location; 1 missing impact angle ZX)

D| PROTOTYPES

HANS Devices

Developed

Concepts
Prototypes

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Prototype 1

Using foams

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Prototype 1

Phase 2

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Prototype 2

Using elastic bands

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Prototype 3

Using airbag

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Comparison

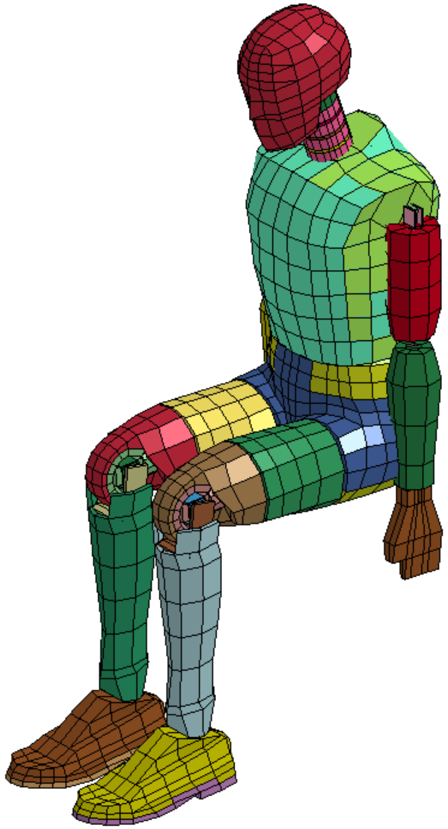
Dainese hybrid neck brace and prototypes

TYPE	WEIGHT	COMFORT (TO WEAR)	COMFORT (WHILE RIDING)	RIDER'S DYNAMICS	FUNCTIONAL POSSIBILITY	PROBLEMS	INJURY PROTECTION ?
	610 gm	(Ref)	(Ref)	(Ref)	Extension Flexion Lateral bending Torsion	- Placing and keeping the brace fixed - Shear effect due to hardness laterally	
	235 gm	▲	▲	▬	Extension Flexion Lateral bending Torsion	- Position of the foams - Shape of the foams - Shear effect due to hardness laterally	
	90 gm	▼	▲	▲	Extension Flexion Lateral bending Translation	- Fixing the system with helmet & jacket - Opening	
	220 gm (deflated)	▲	▲	▲	Extension Flexion Lateral bending Compression	- The thickness during the inflated condition - Difficulty in properly designing the geometries	

D| NUMERICAL METHODS

Dummy
Models

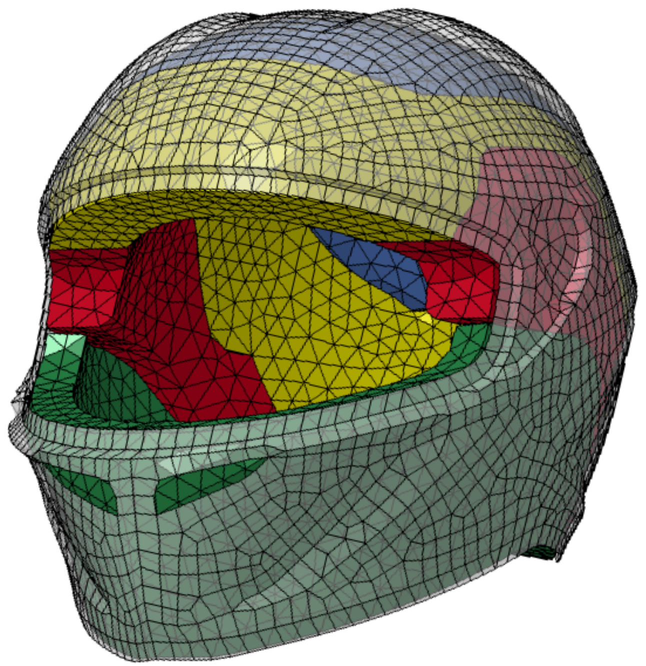
HYBRID III 50th PERCENTILE MALE



HYBRID III DUMMY DEVELOPED AND DISTRIBUTED BY LSTC

Helmet
Models

PISTA GP AGV E2205 MULTI GRAN PREMIO



***AG400: COMPOSITE SHELL + EPS PADDING**

*The helmet model has been provided by Alessandro Cernicchi ©

Neck Protecting Devices

Models

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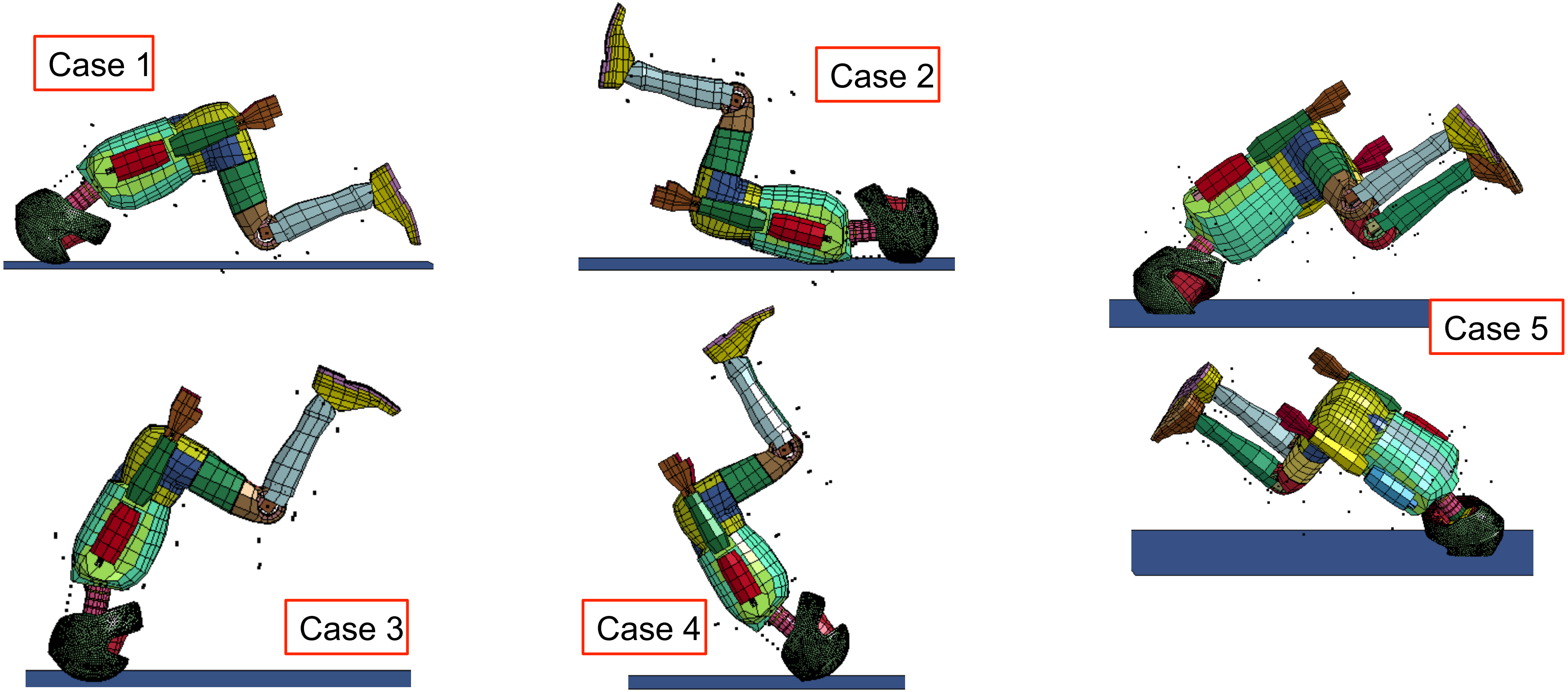
Different Scenarios

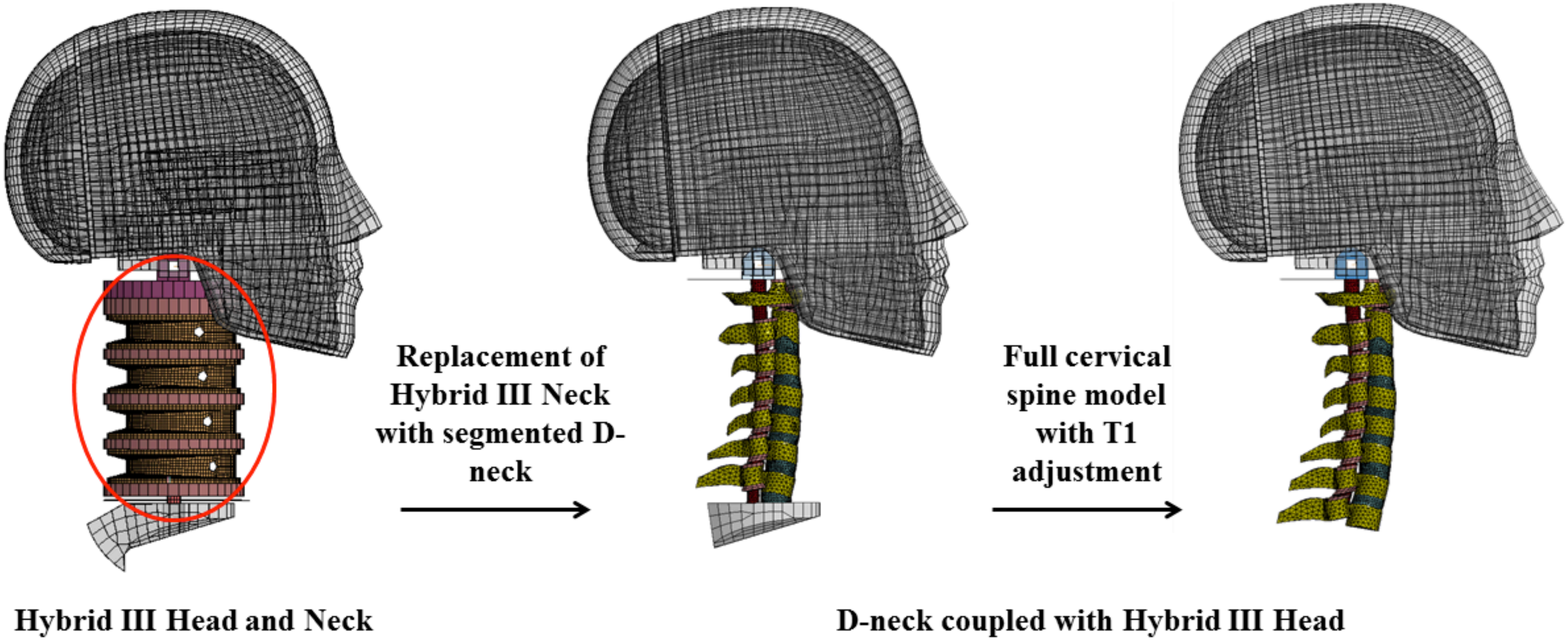
Impact analysis



D| NECK FE MODEL

A Simple 3D Neck Model

Development of D-neck model



Validation of the Model

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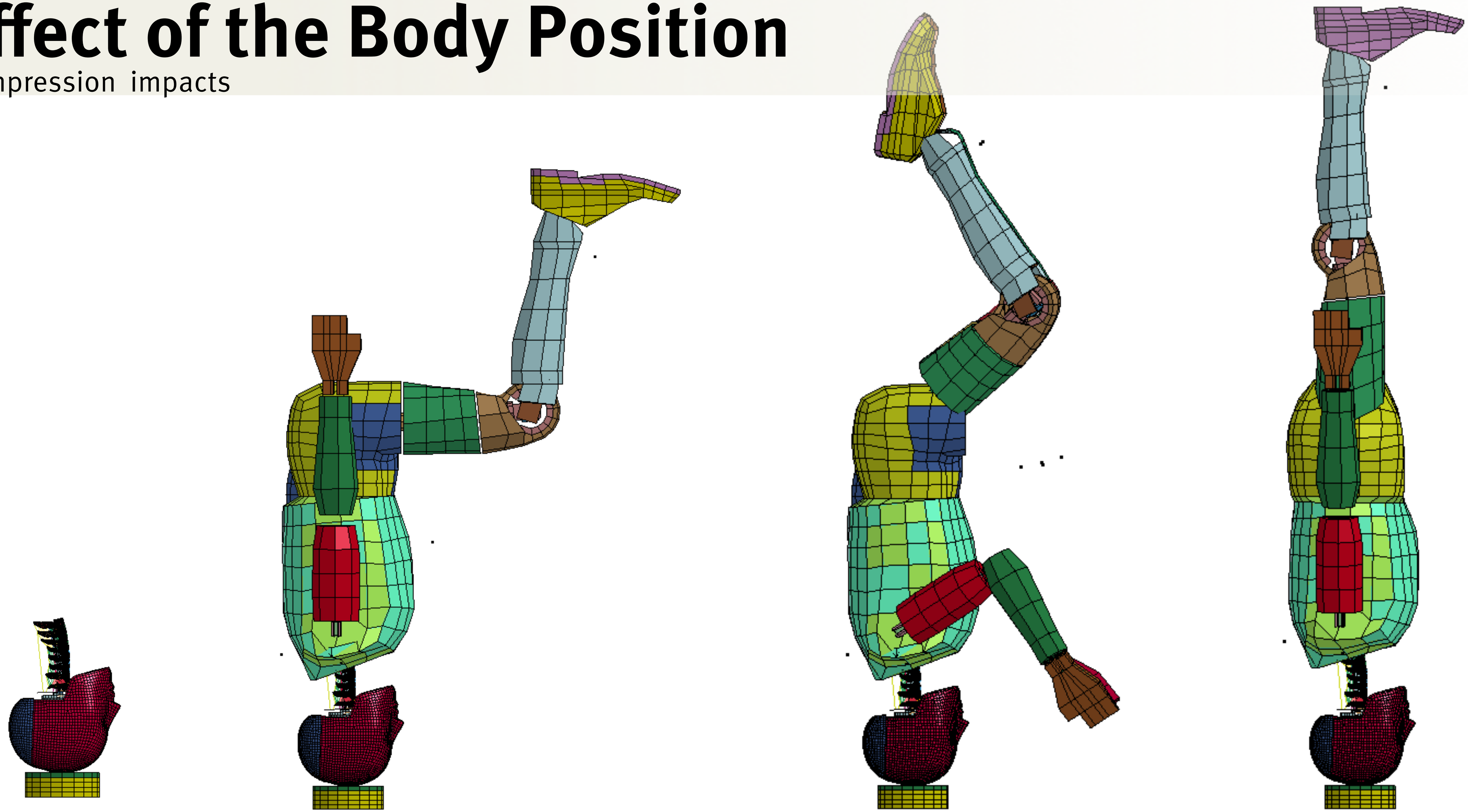
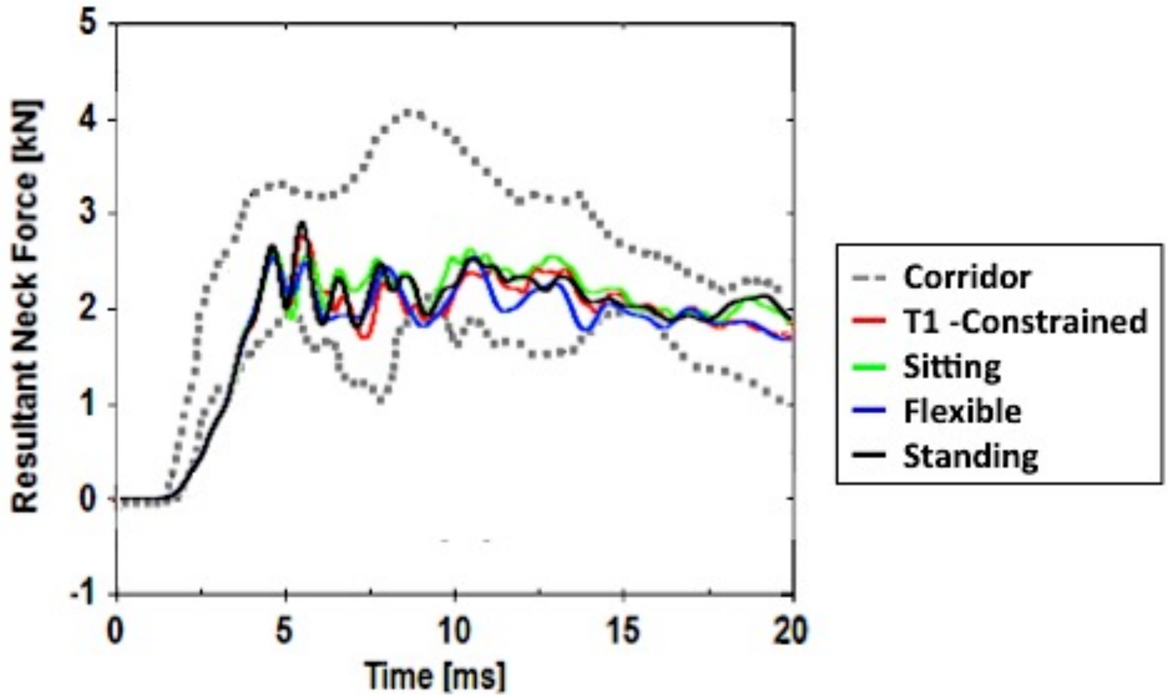
Effect of the Body Position

Compression impacts



Effect of the Body Position

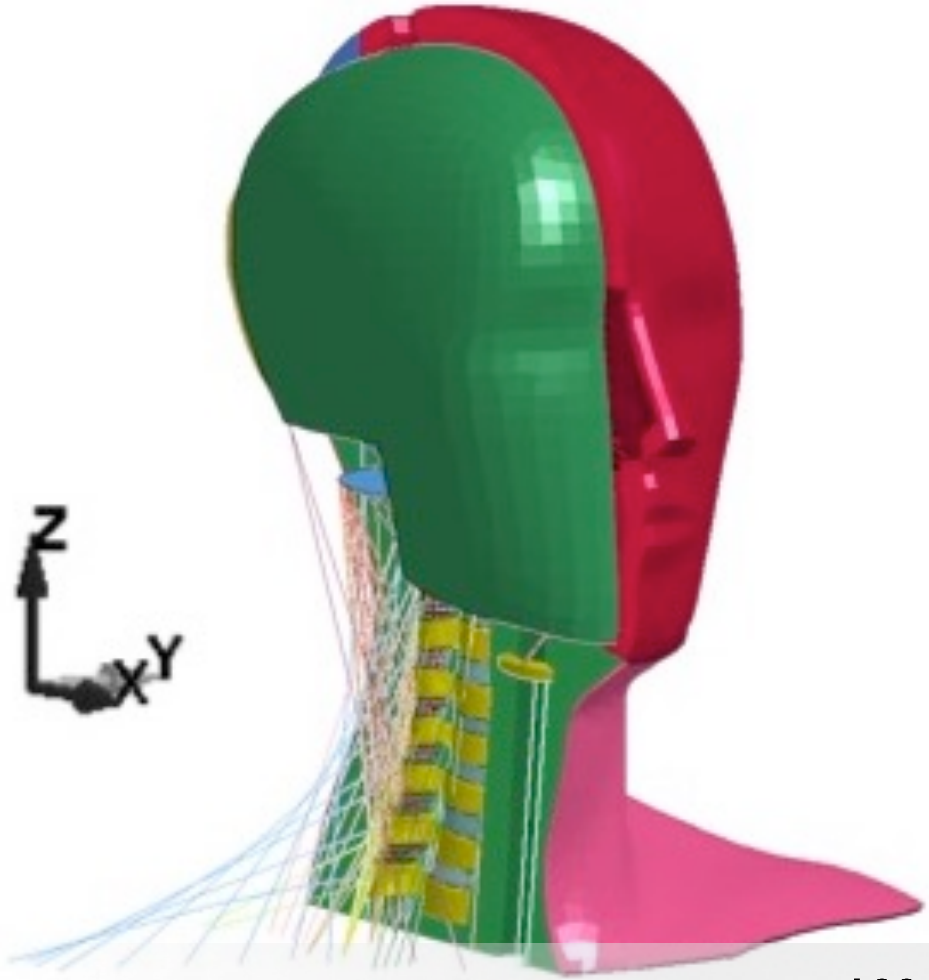
Nightingale's compression impacts

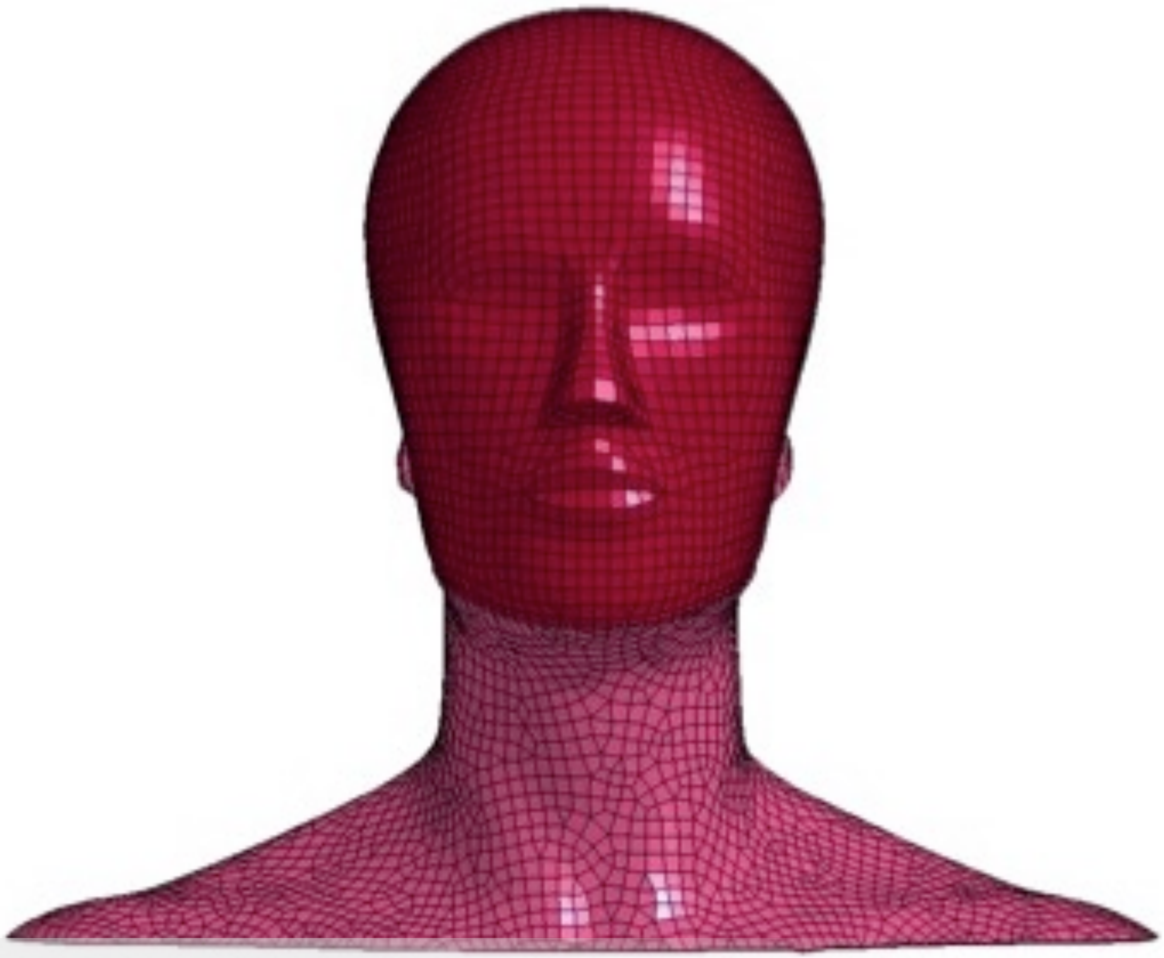


Nasim M., Cernicchi, A., Galvanetto U., The Effect Of Human Body Positioning On Neck Injuries During Compressive Impacts, Proceeding of International Conference on Impact Loading of Structures and Materials, Xi'an, China, 2018.

A Simple 3D Neck Model

Development of D-neck model





169060 elements

Validation of the Model

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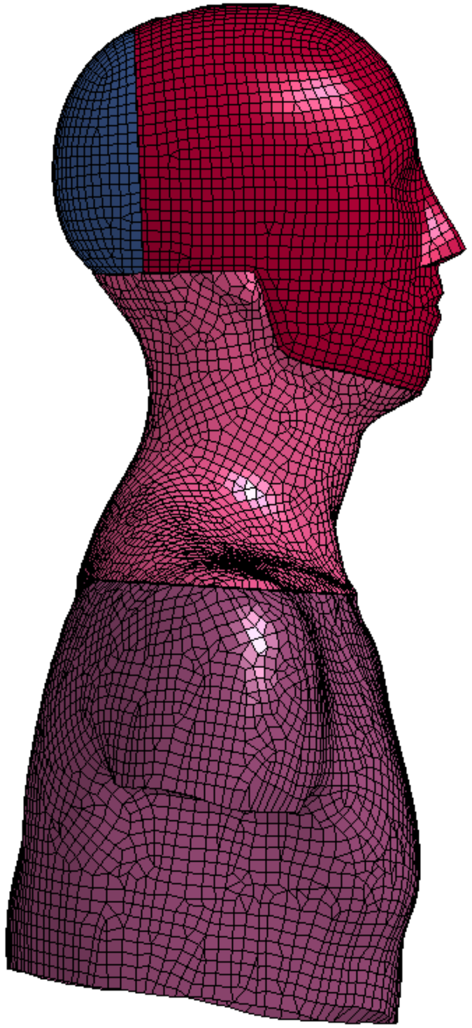
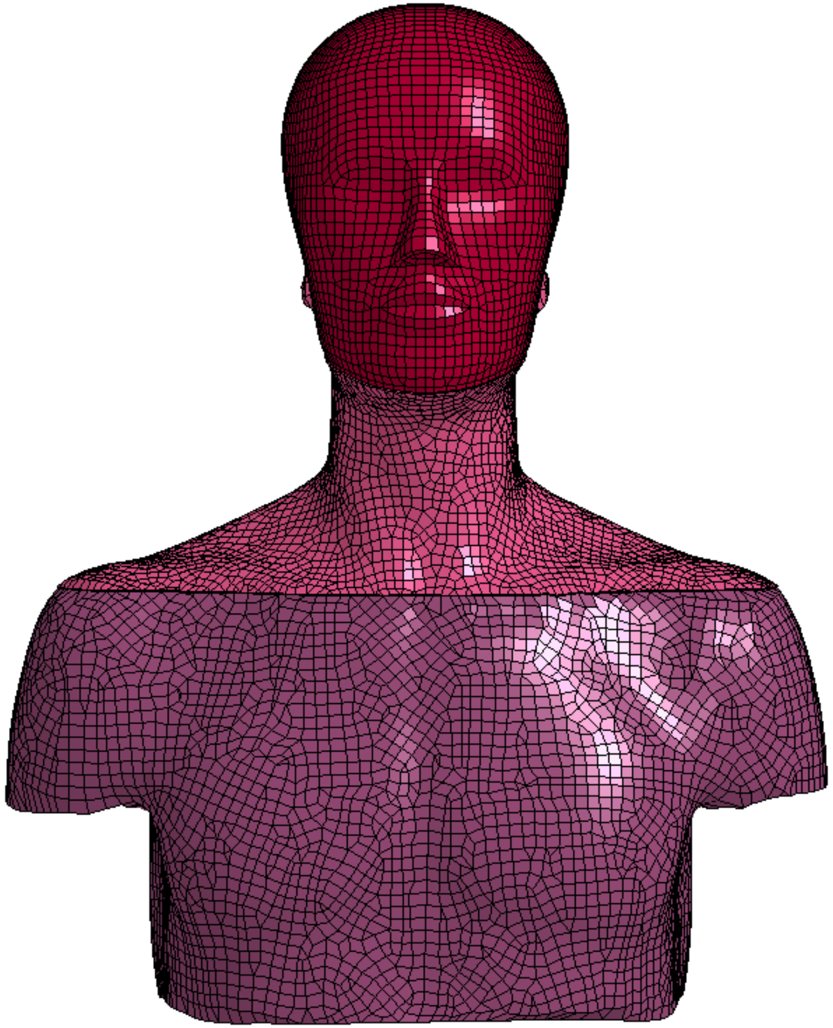
Experimental Model

Assumption of the test dummy model





Case 1: Sliding +15°

Probable experimental setup

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Case 2: Sliding -15^0

Probable experimental setup

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Case 3: Sliding Lateral

Probable experimental setup

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Case 4: Inverted +15°

Probable experimental setup

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Case 5: Inverted 0º

Probable experimental setup

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Case 6: Inverted -15°

Probable experimental setup

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D| NEXT STEPS

Future Needs

Discussion

- Other anthropomorphic Human models specially Head-Neck model.
- Different helmet models.
- Expertise for the Standard development.
  - Biomechanical Department
  - Test-houses
- Adjustment of the problems observed in the prototypes.
- Experimental set-up for practical evaluation.
  - Head position relative to torso.
  - Neck axial and shear forces.
  - Neck bending moment at occipital condyles.

Standards

A draft proposal

- Innocuousness and Ergonomics.
- New Neck Anthropomorphic Test Device.
- New Test Method(s)
- Neck Injury Assessment Metric(s).

Development of the Experimental Setup

Anthropomorphic test device

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Publications

Deliverable

Nasim M. , Brasca M. , Cernicchi A. , Silani E. ; *Standards in PPE, A survey*, http://www.motorist-ptw.eu/wp-content/uploads/2015/10/MOTORIST-D3.5_Standards-in-PPE-a-survey.pdf, 2015.

Conference

Nasim M., Cernicchi A., Galvanetto U., The Effect Of Human Body Positioning On Neck Injuries During Compressive Impacts, 2018, Xi'an, China.

Nasim M. , Brasca M. , *Impact properties of polymeric materials used for motorcyclists' personal protective equipment*, International Conference on Impact Loading of Structures and Materials, 2016.

Nasim M. , The introduction to the personal protective equipments for motorcyclists, MCAA General Assembly and Annual Conference, 2016. (Poster).

Journal

Nasim M. , Brasca M. , Khosroshahi S. F. , Galvanetto U. , *Understanding the impact properties of polymeric sandwich structures used for motorcyclists' back protectors*, Polymer Testing. Vol. 61, pp 249-257. Doi: doi.org/10.1016/j.polymertesting.2017.05.025.

GRAZIE

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