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Design of experiments for the evaluation of the human - exoskeleton interaction in the context of small data collections

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Context and General Objectives:

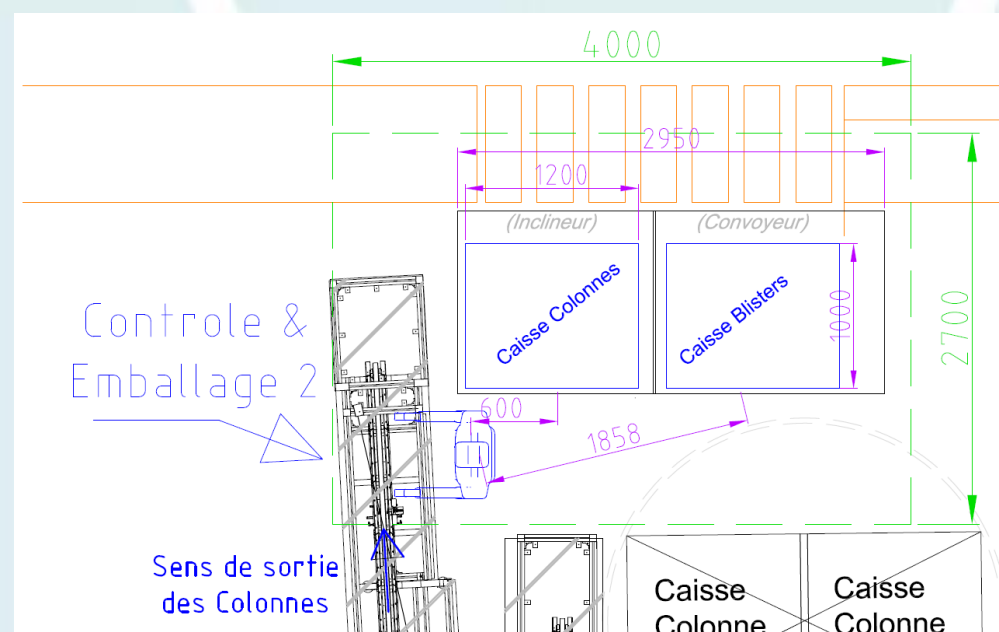
ThyssenKrupp company which manufactures steering columns have undertaken a **systemic approach** including managers and operators in order to better support the transformations of the work to respond to the health and safety issues facing these new practices. In this subsidiary, experiments are in progress on load-bearing exoskeleton devices designed to relieve operators of some of the most difficult tasks.

A scientific study, jointly conducted with the University of Lorraine, on workstations located at the end of the production line should make it possible to identify the effects of such assistance systems on the biomechanical and psychological risk factors of the operators.



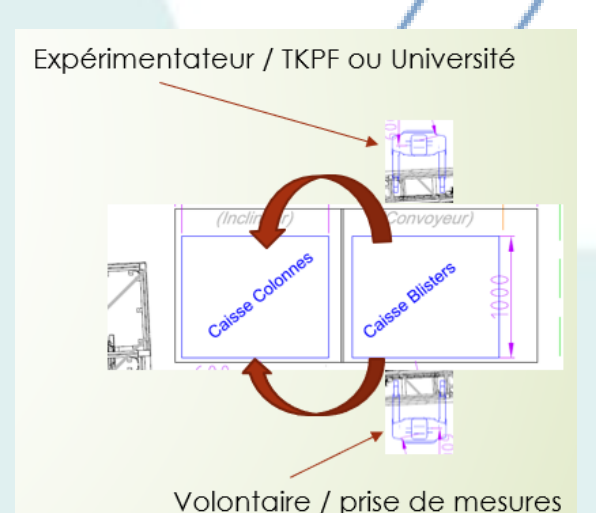
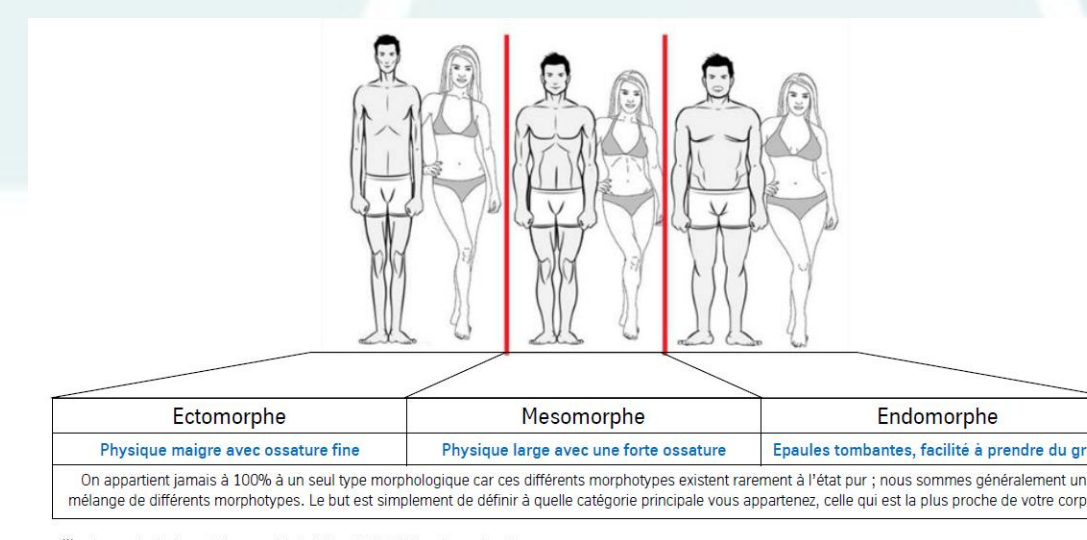
The mock-up of the workstation in a laboratory context:

- Reproduction of the 1086 line
- Simulation of production rate
- The level of noise and temperature
- Personal protective equipment



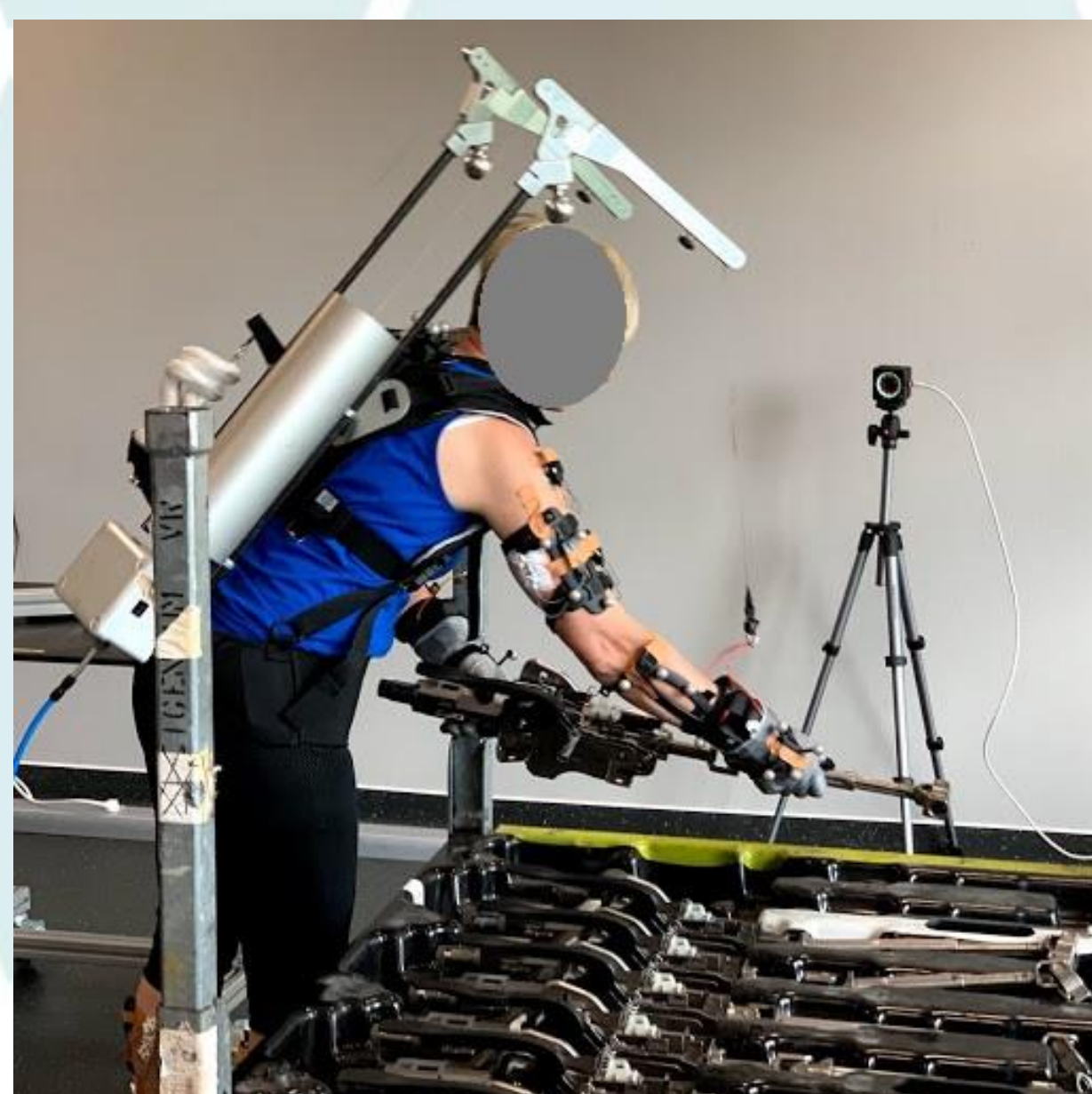
Design of experiments:

- Six real operators (N=6)
- 3 females and 3 males that represents different somatotypes and heights
- 8 experiments with and without exoskeleton
- 1/2 day of measurements per voluntary
- Evaluation of the manipulation of steering depending the height of the rack
- Evaluation of a co-manipulation of the racks



A multimodal measurement protocol:

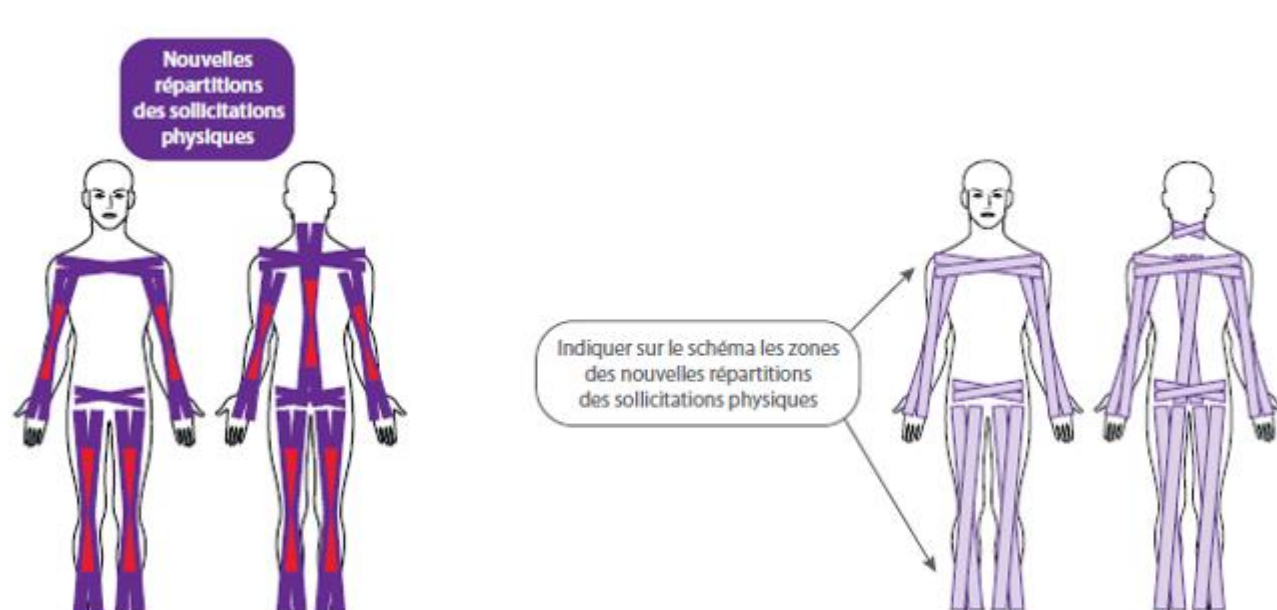
- Comparison of subjective survey of perceived exertion (with/without exoskeleton – CR10, échelle de Borg)
- Evaluation of the upper and the lower body activity with Electromyographic system (Delsys)
- Kinematic measures with Motion Capture system (Optitrack)
- Posture analysis with force plate (AMTI)
- Heart rate during the exertion (Garmin)



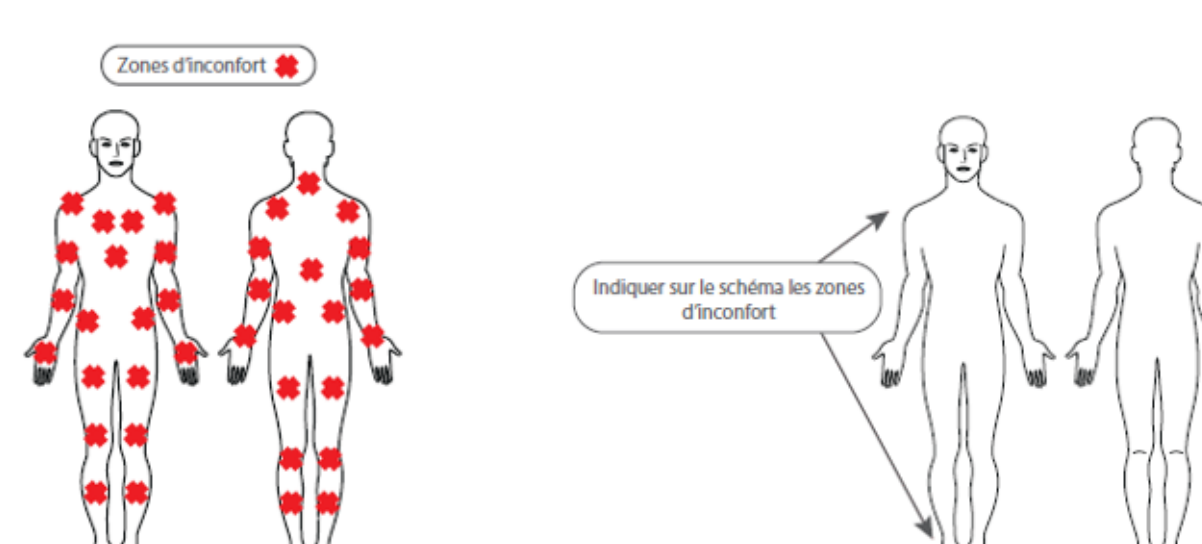
Identification des zones d'assistance :



Nouvelles sollicitations physiques :



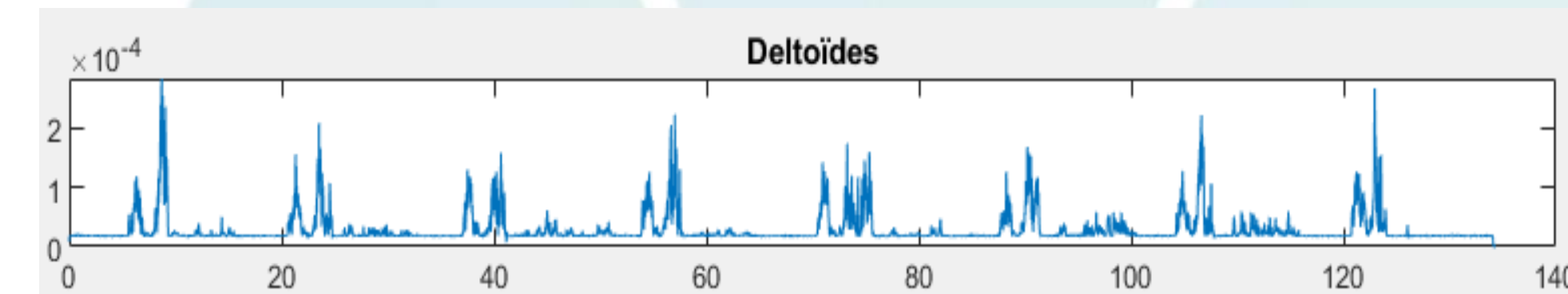
Zones d'inconfort :



Data process workflow:

extraction of biomarkers during 2 phases pick and place of the steering columns
extraction of biomarkers during 2 phases pick and place of the racks

- Signals synchronization and data transformation
- Biomarkers of biomechanics : angle, speed, stability and precision of upper body segments (quaternions data process on Matlab)
- Biomarkers of neuromuscular : EMG signal processing (RMS value of each phase)

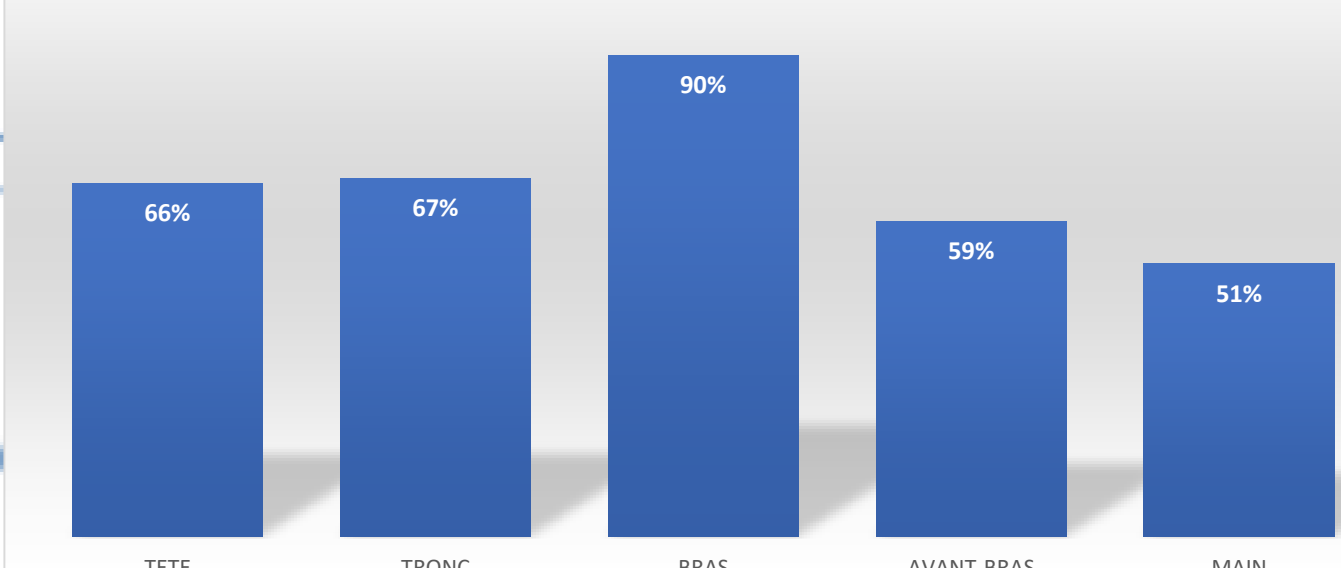


- Biomarkers of human postural control (statokinesigram and center of pressure analysis)
- Mapping of the different conditions of work tasks depending of the place of steering column in the rack

Preliminary results:

TETE			TRONC			BRAS		AVANT-BRAS		MAIN	
Tête élévation regard	Tête flexion latérale	Tête torsion	Tronc flexion AV/AR	Tronc flexion latérale	Tronc torsion	Bras flexion	Bras abduction	Avt Bras élévation	Avt Bras torsion	Main flexion	Main flexion latérale
65	22	44	11	59	22	56	23	57	14	58	20
75	29	88	12	35	22	42	34	47	16	41	11
58%	19%	39%	10%	52%	19%	50%	20%	50%	12%	51%	18%
77%	49%	49%	72%	70%	20%	50%	12%	63%	60%	68%	26%
66%				70%		67%		90%		59%	

Taux d'exposition posturale par partie du corps vs. criticité ergonomique rouge & jaune



Coût cardiaque moyen (% augmentation vs. FCRepos)

