Table 1: NASA 7009A Credibility Factors Considered in this study and the corresponding descriptions.

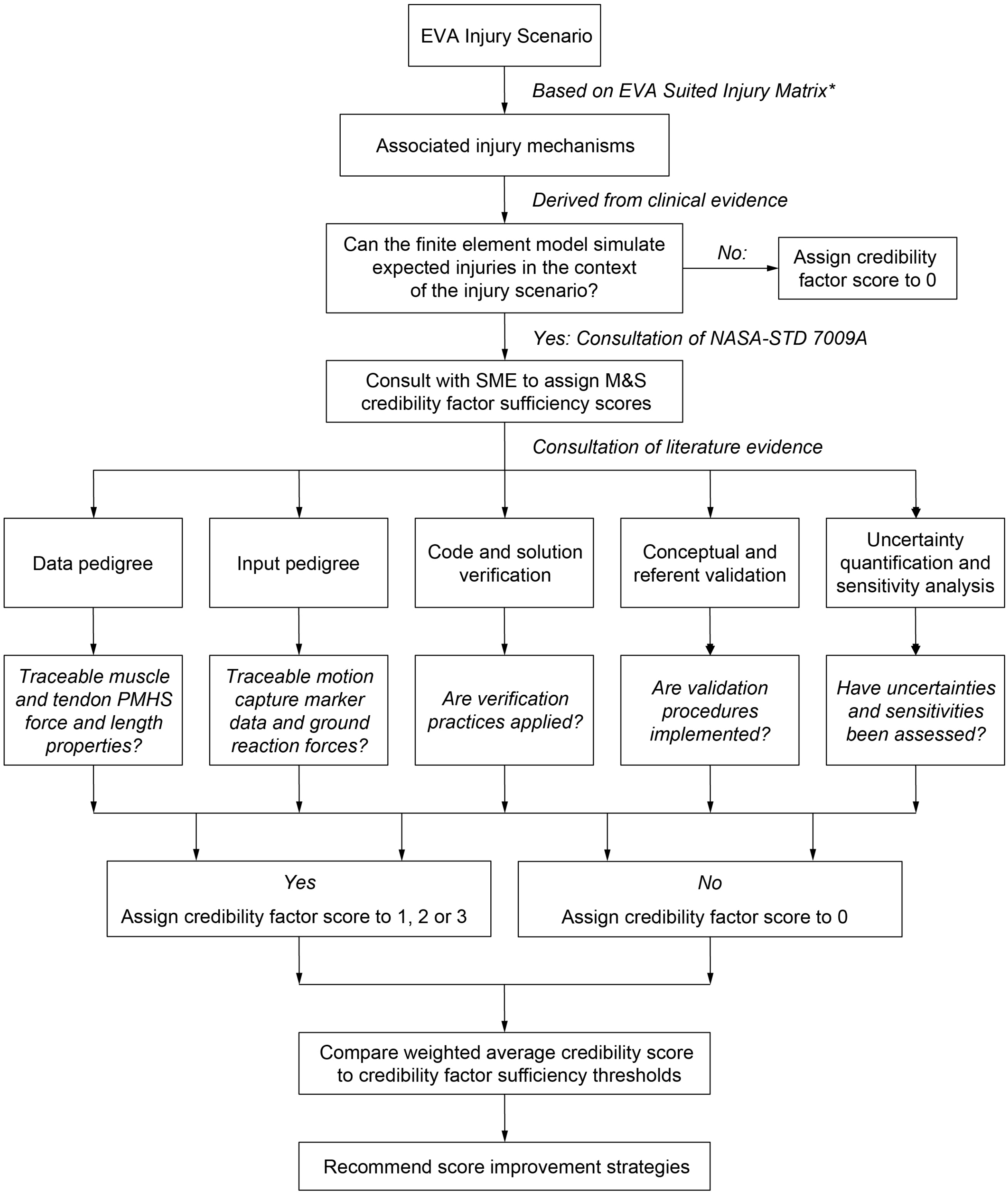
Credibility Factor	*Data Pedigree*	*Input Pedigree*	*Code/ Solution Verification*	*Conceptual/ Referent Validation*	*Results Uncertainty*	*Results Robustness*
Credibility Sufficiency Threshold	2	2	2	3	3	3
Model Relations	Material Properties	Input boundary conditions/ contact	Verification Analysis	Validation Analysis	Uncertainty Quantification	Sensitivity Analysis
Description	Data supplying the conceptual implementation	Data supplying the boundary/ initial conditions	Evidence the concept is implemented correctly	Evidence the concept resembles the real-world system of interest	Propagation of variations throughout the FE model for the input conditions and properties specified	Changes in the outputs of the simulation due to variations in the input and design of the FE model

Table 2: Summary of elevation strategies and corresponding score updates for the Elemance FE model for injury mechanisms within the fall from heights injury scenario.

Injury Mechanism	M&S Credibility Factor	Original Credibility Score	Score Improvement Potential	Elemance Simplified Pedestrian Finite Element Model Credibility Enhancement Strategy
Vertebral	Data Pedigree	1	2	Add deformable vertebral bone (cervical, thoracic), add IVD inclusions (cervical, lumbar) correlating to experimental properties.
	Input Pedigree	0	1	Contact properties and loading inputs between vertebrae should be updated using experimental evidence.
	Code/Solution Verification	0	2	Code and solution verification analysis need to be assessed for key anatomical regions within the FFH scenario.
	Conceptual Validation	1	2	Conduct stress-state conceptual assessments to determine reliability in the vertebral model.
	Conceptual Validation	1	2	Update of constitutive models to capture stress and strain rate dependencies are needed for vertebral bone and IVD
	Referent Validation	1	3	Conduct validation cases in a prone, supine, top, and standing conditions for FFH relevant velocities showing good agreement.
	Results Uncertainty	0	2	Quantify most sources of uncertainty associated with the simulations within the FFH scenario and identify key uncertainties.
	Results Robustness	1	2	Assess sensitivities associated with key material properties.
Lower Limb	Data Pedigree	1	2	Add deformable ankle/foot elements with traceable material properties and 2-D and 3-D elements for ankle ligaments.
	Data Pedigree	1	2	Add traceable material data for patella bone and knee ligaments
	Input Pedigree	0	2	Friction coefficients specified for the contact between regions should be updated based on experimental evidence
	Code/Solution Verification	0	2	Code and solution verification analysis need to be assessed for key anatomical regions within the FFH scenario.
	Conceptual Validation	1	3	Perform additional conceptual assessments using dynamic strain rates in compression, shear, and bending stress states
	Referent Validation	1	2	Perform additional validation cases in a prone, supine, lateral, and standing (velocities exceeding 8m/s) with good agreement to experiments.
	Results Uncertainty	0	2	Quantify most sources of uncertainty associated with the simulations within the FFH scenario and identify key uncertainties.
	Results Robustness	0	2	Assess key sensitivities related to the material properties and FFH boundary conditions.
Thoracic	Data Pedigree	1	2	Material properties for soft tissues, sternum, and rib cortical bone should be updated with experimental derived evidence.
	Code/Solution Verification	0	2	Code and solution verification analysis need to be assessed for key anatomical regions within the FFH scenario.
	Conceptual Validation	2	3	Conduct conceptual evaluation of axial impacts to the ribs along with evaluation of remainder of features in this region
	Referent Validation	2	3	Perform referent validation cases in prone, supine, and lateral impact conditions with good experimental agreement
	Results Uncertainty	0	2	Quantify most sources of uncertainty associated with the simulations within the FFH scenario and identify key uncertainties.
	Results Robustness	1	2	Assess key sensitivities related to the material properties and FFH boundary conditions
Shoulder	Data Pedigree	0	2	Soft tissue representations should be added along with traceable material properties throughout the full region
	Input Pedigree	0	2	Friction coefficients and joint loading curves should be updated based on anatomically appropriate experimental data.
	Code/Solution Verification	0	2	Code and solution verification analysis need to be assessed for key anatomical regions within the FFH scenario.
	Conceptual Validation	0	3	Assess the anatomical features to evaluate the resemblance of the RWS in simulations.
	Referent Validation	1	2	Conduct Prone, supine, and standing referent validation cases.
	Referent Validation	1	3	Show improved agreement in a lateral impact orientation.
	Results Uncertainty	0	2	Quantify most sources of uncertainty associated with the simulations within the FFH scenario and identify key uncertainties.
	Results Robustness	0	2	Perform assessments for key sensitivities related to the material properties and FFH boundary conditions.

Table 3: Summary of elevation strategies and corresponding score updates for the THUMS FE model for injury mechanisms within the fall from heights injury scenario.

Injury Mechanism	M&S Credibility Factor	Original Credibility Score	Score Improvement Potential	THUMS Finite Element Model Credibility Enhancement Strategy
Vertebral	Data Pedigree	1	2	Update cervical ligaments, meninges, spinal cord, cervical muscle activation with traceable evidence.
	Data Pedigree	1	1	Update cortical vertebral bone with corresponding anatomical experimental derivations.
	Input Pedigree	1	2	Update contact coefficients (especially for IVD-cortical bone contact) based on observed evidence from RWS.
	Code/Solution Verification	0	2	Perform Code and solution verification analysis for key anatomical regions within the FFH scenario.
	Conceptual Validation	1	3	Conduct dynamic stress-state dependent validations of vertebral interface with good agreement to experiments.
	Referent Validation	1	3	Perform additional validation cases for supine, lateral, top, standing orientations for FFH velocities.
	Referent Validation	1	1	Perform validation cases for prone orientation below 10m/s with good agreement to experiments.
Lower Limb	Data Pedigree	1	2	Update menisci, patella bone, ankle/foot tendons and ligaments with traceable experimental data.
	Data Pedigree	1	1	Update trabecular bone with experimental data from appropriate anatomical sources.
	Data Pedigree	1	2	Add muscular anatomy and activation features, BMD considerations for fracture, and stress-state and strain rate properties.
	Input Pedigree	1	2	Update contact coefficients between cortical bone and soft tissues based on observed evidence from RWS.
	Input Pedigree	1	1	Evaluate knee and ankle joint constraints to ensure boundary conditions in FFH can be captured.
	Code Verification	1	2	Conduct a verification of fibula and ankle ligament models should be conducted for an evaluation of the physics-based representations.
	Solution Verification	0	2	Conduct Mesh convergence studies for key features.
	Conceptual Validation	1	3	Perform dynamic assessments of fibula and femur in bending and compression stress-states with good experimental agreement.
	Conceptual Validation	1	3	Perform ankle and knee joint validation in dynamic flexion and extension.
	Referent Validation	2	2	Conduct prone orientation validation using impact velocities beyond 5m/s.
	Referent Validation	2	3	Show improved Agreement in lateral and standing impact orientations.
Thoracic	Data Pedigree	1	2	Update material properties for rib trabecular bone, sternum bone, and rib soft tissues with traceable anatomically representative experimental data.
	Input Pedigree	1	2	Update contact coefficients with experimental data.
	Input Pedigree	1	2	Evaluate constraints between cortical bone and rib ligaments to ensure resemblance of RWS.
	Code/Solution Verification	0	2	Perform Code and solution verification analysis for key anatomical regions within the FFH scenario.
	Conceptual Validation	1	3	Conduct dynamic axial and bending stress-state validations of anterior thoracic.
	Referent Validation	1	3	Perform validation in supine and lateral impact orientations at FFH relevant velocities with good experimental agreement.
Shoulder	Data Pedigree	1	2	Update bone material properties with anatomically appropriate data derived from experiments
	Data Pedigree	1	2	Update ligaments should be updated based on traceable experimental data.
	Input Pedigree	1	2	Update contact coefficients with experimentally derived values.
	Input Pedigree	1	2	Update joint movement with loading conditions to model interaction with xEMU suit in the FFH scenario.
	Code/Solution Verification	0	2	Perform Code and solution verification analysis for key anatomical regions within the FFH scenario.



* Denotes the Suited Injury Matrix and FY21 plan version (Reiber et al., 2022)

Figure 1: Flow chart for the falls from height injury scenario credibility assessment performed in this study.

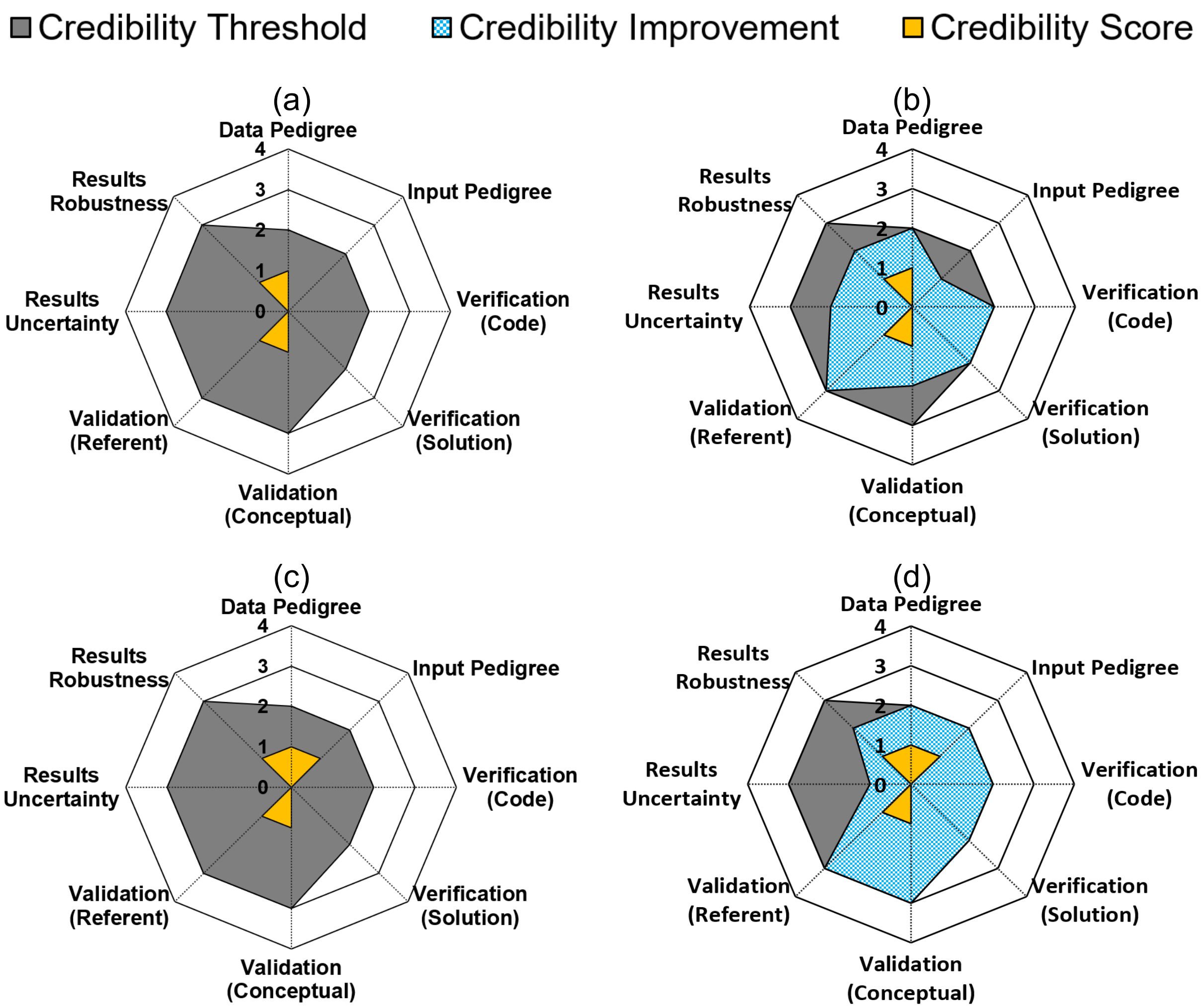


Figure 2: Results of the M&S credibility assessment for the vertebral injury mechanism showing the ordinal credibility factor scores (a) and potential elevated credibility factor scores (b) for the Elemance model and the ordinal credibility factor scores (c) and potential elevated credibility factor scores (d) for the THUMS model.

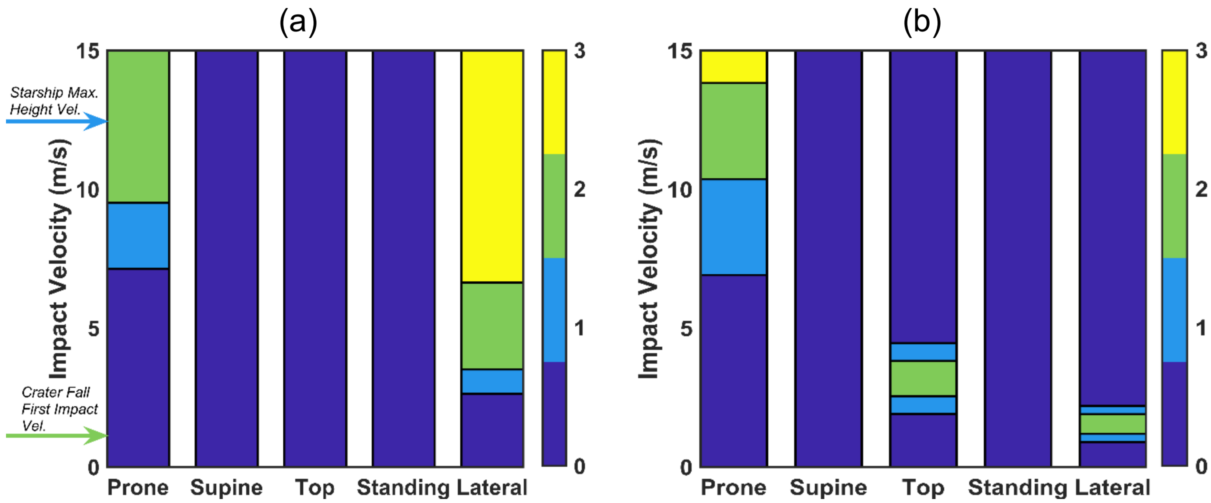


Figure 3: Fall from heights injury scenario credibility heat map describing the impact velocity ranges assessed in the available literature for the Elemance (a) and THUMS (b) FE models in the vertebral injury mechanism.

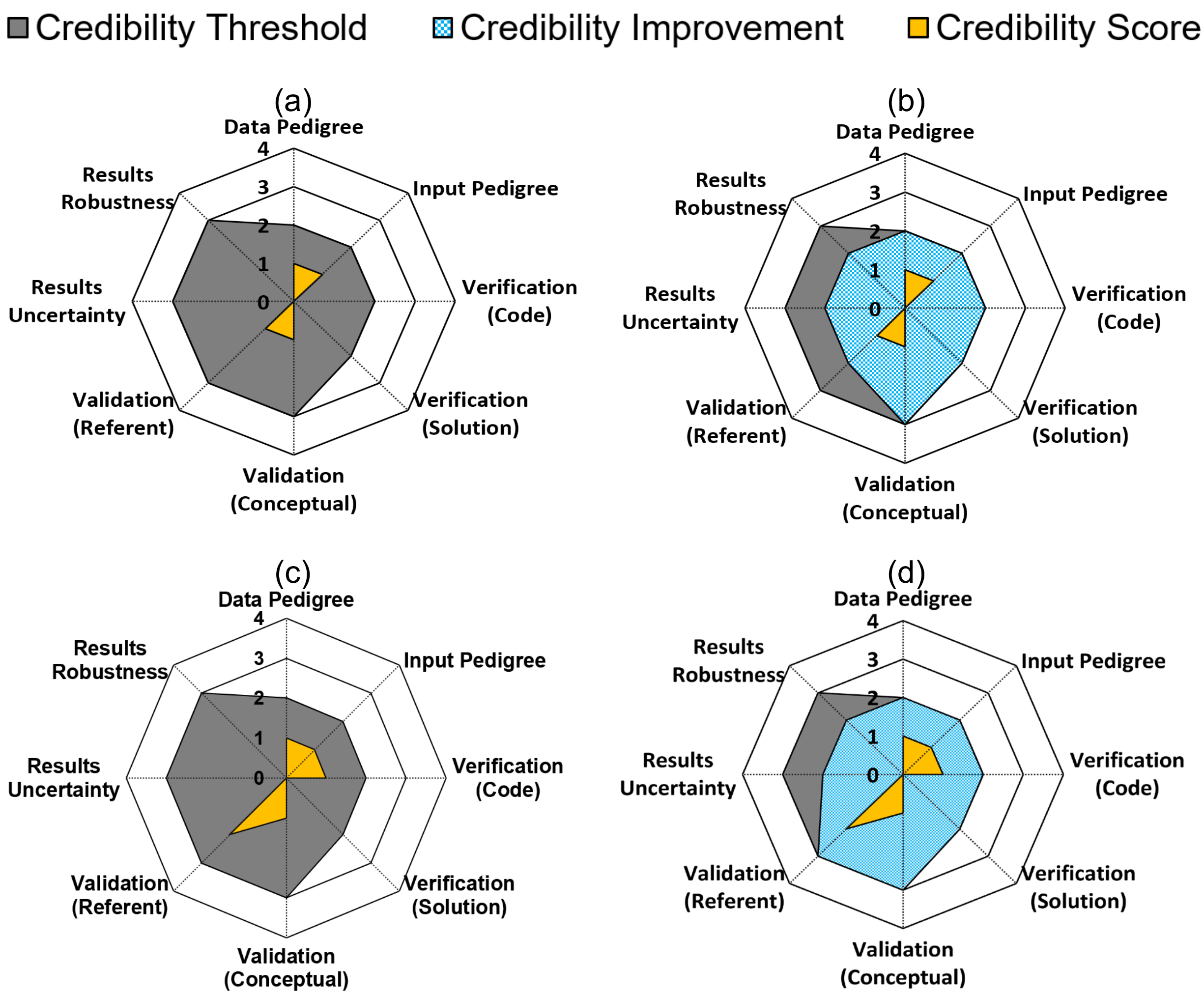


Figure 4: Results of the M&S credibility assessment for the lower limb injury mechanism showing the ordinal credibility factor scores (a) and potential elevated credibility factor scores (b) for the Elemance model and the ordinal credibility factor scores (c) and potential elevated credibility factor scores (d) for the THUMS model.

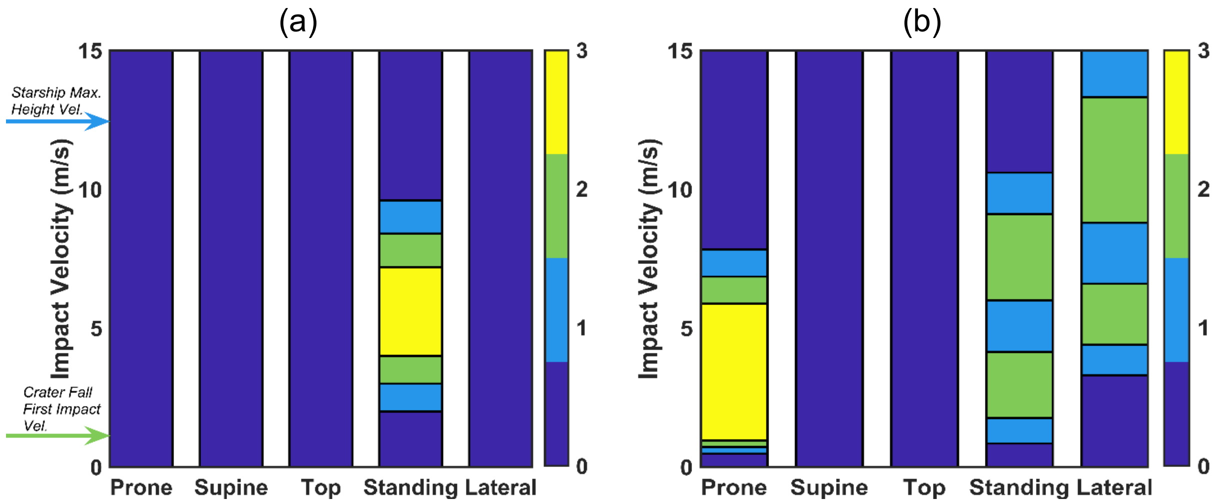


Figure 5: Falls from heights injury scenario credibility heat map describing the impact velocities ranges assessed in the available literature for the Elemance (a) and THUMS (b) FE models for the lower limb injury mechanism.

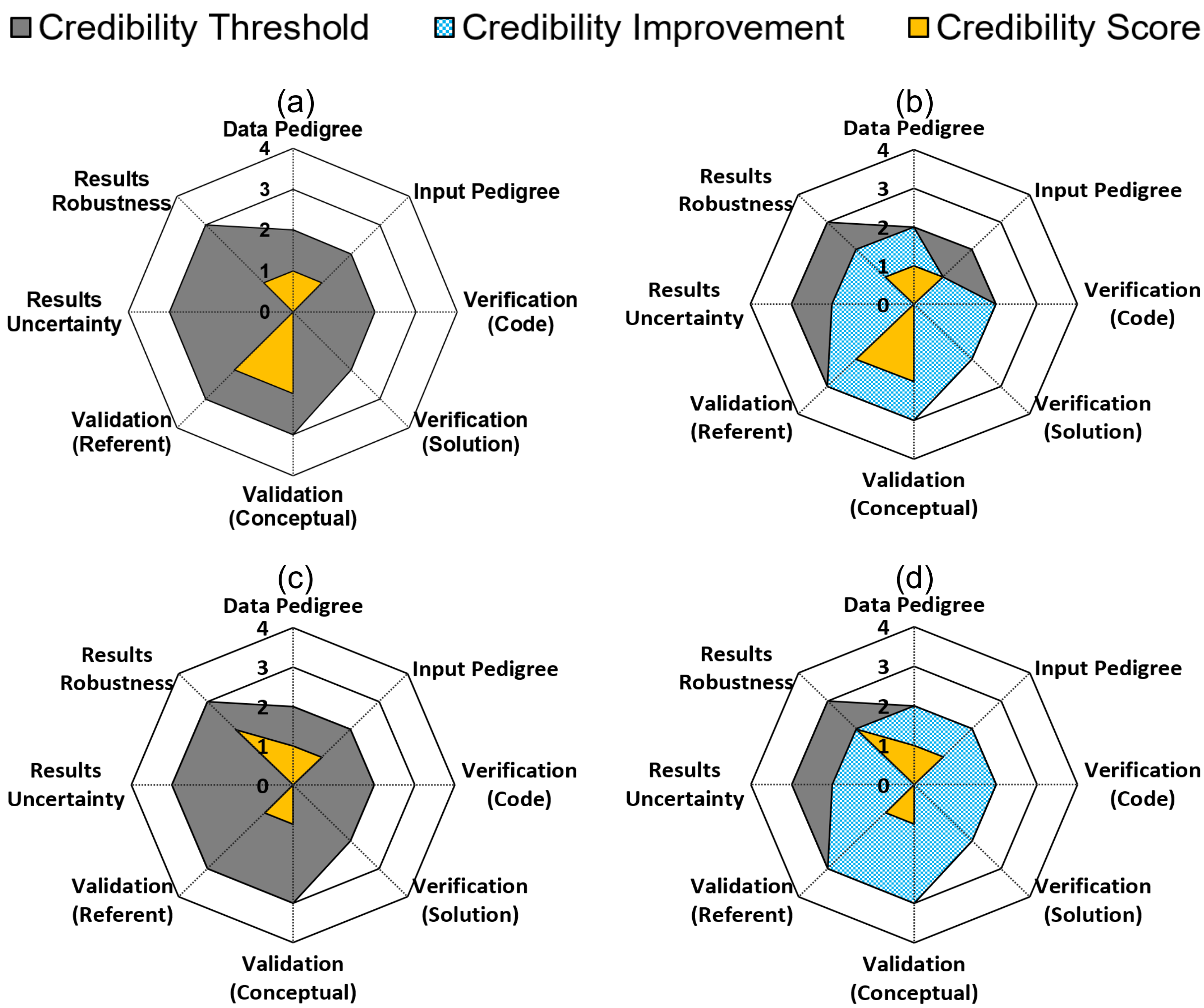


Figure 6: Results of the M&S credibility assessment for the thoracic injury mechanism showing the ordinal credibility factor scores (a) and potential elevated credibility factor scores (b) for the Elemance model and the ordinal credibility factor scores (c) and potential elevated credibility factor scores (d) for the THUMS model.

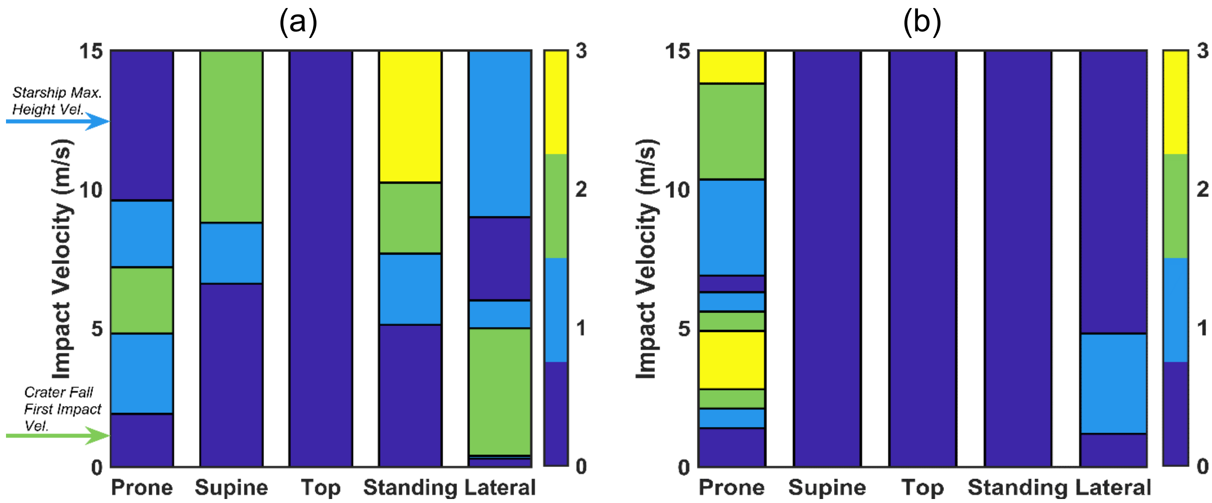


Figure 7: Falls from heights injury scenario credibility heat map describing the impact velocities ranges assessed in the available literature for the Elemance (a) and THUMS (b) FE models for the thoracic injury mechanism.

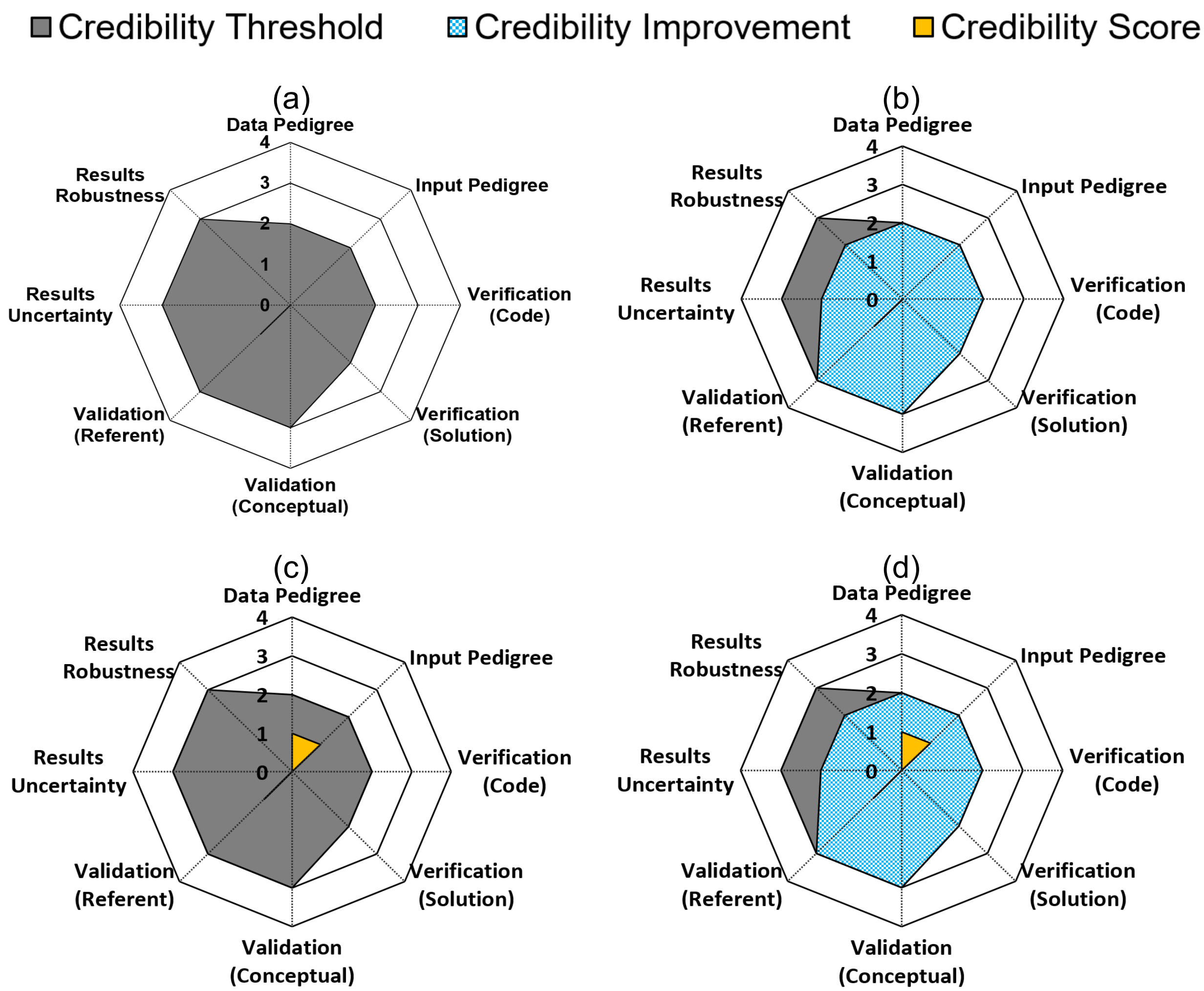


Figure 8: Results of the M&S credibility assessment for the shoulder injury showing the ordinal credibility factor scores (a) and potential elevated credibility factor scores (b) for the Elemance model and the ordinal credibility factor scores (c) and potential elevated credibility factor scores (d) for the THUMS model.

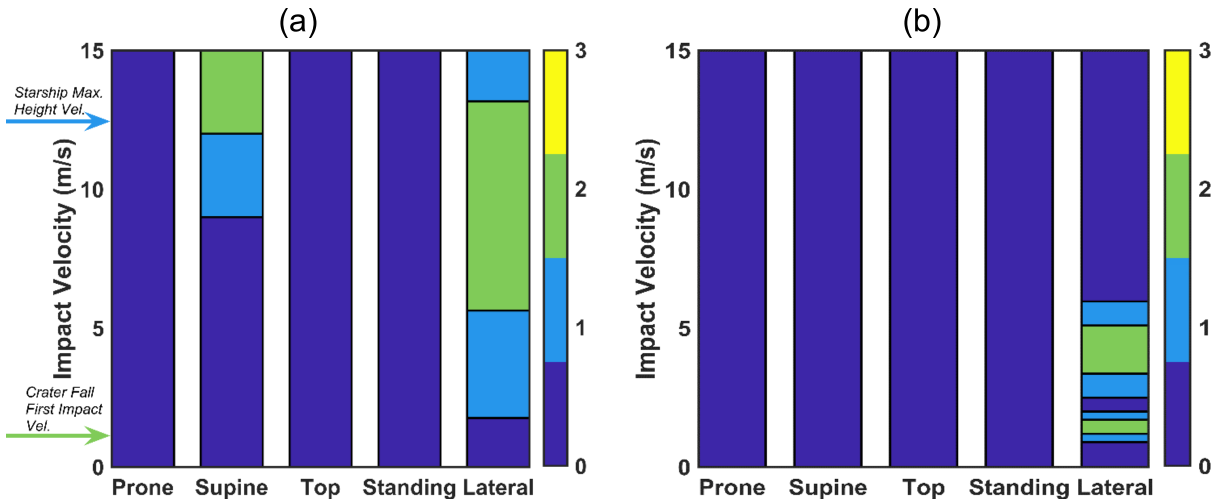


Figure 9: Falls from heights injury scenario credibility heat map describing the impact velocities ranges assessed in the available literature for the Elemance (a) and THUMS (b) FE models for the shoulder injury mechanism.

Figure Captions:

Figure 1: Flow chart for the falls from height injury scenario credibility assessment performed in this study.

Figure 2: Results of the M&S credibility assessment for the vertebral injury mechanism showing the ordinal credibility factor scores (a) and potential elevated credibility factor scores (b) for the Elemance model and the ordinal credibility factor scores (c) and potential elevated credibility factor scores (d) for the THUMS model.

Figure 3: Fall from heights injury scenario credibility heat map describing the impact velocity ranges assessed in the available literature for the Elemance (a) and THUMS (b) FE models in the vertebral injury mechanism.

Figure 4: Results of the M&S credibility assessment for the lower limb injury mechanism showing the ordinal credibility factor scores (a) and potential elevated credibility factor scores (b) for the Elemance model and the ordinal credibility factor scores (c) and potential elevated credibility factor scores (d) for the THUMS model.

Figure 5: Falls from heights injury scenario credibility heat map describing the impact velocities ranges assessed in the available literature for the Elemance (a) and THUMS (b) FE models for the lower limb injury mechanism.

Figure 6: Results of the M&S credibility assessment for the thoracic injury mechanism showing the ordinal credibility factor scores (a) and potential elevated credibility factor scores (b) for the Elemance model and the ordinal credibility factor scores (c) and potential elevated credibility factor scores (d) for the THUMS model.

Figure 7: Falls from heights injury scenario credibility heat map describing the impact velocities ranges assessed in the available literature for the Elemance (a) and THUMS (b) FE models for the thoracic injury mechanism

Figure 8: Results of the M&S credibility assessment for the shoulder injury showing the ordinal credibility factor scores (a) and potential elevated credibility factor scores (b) for the Elemance model and the ordinal credibility factor scores (c) and potential elevated credibility factor scores (d) for the THUMS model.

Figure 9: Falls from heights injury scenario credibility heat map describing the impact velocities ranges assessed in the available literature for the Elemance (a) and THUMS (b) FE models for the shoulder injury mechanism.

Table Captions:

Table 1: NASA 7009A Credibility Factors Considered in this study and the corresponding descriptions.

Table 2: Summary of elevation strategies and corresponding score updates for the Elemance FE model for injury mechanisms within the fall from heights injury scenario.

Table 3: Summary of elevation strategies and corresponding score updates for the THUMS FE model for injury mechanisms within the fall from heights injury scenario.