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AN INTEGRATED MULTISCALE ANALYSIS OF INJURY MECHANISMS IN SPORT IMPACTS: AN APPLICATION TO CERVICAL SPINE BIOMECHANICS IN RUGBY UNION SCRUMMAGING

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If your abstract is not accepted as an oral do you wish to be considered for a poster?: Yes

Clinical Biomechanics Award: Yes

David Winter Young Investigator Awards: No

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Promising Scientist Award sponsored by Motion Analysis: No

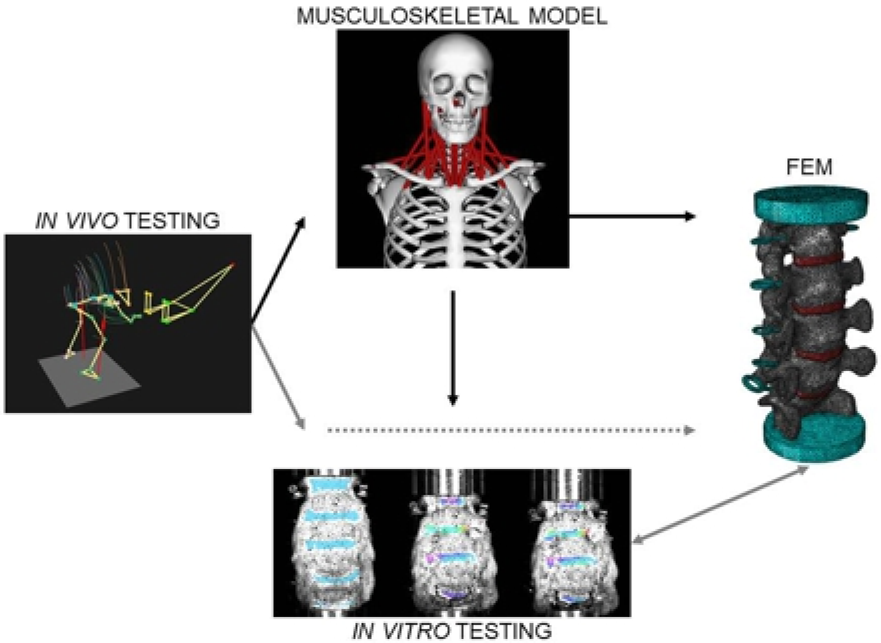
Introduction and Objectives: By generating repetitive high-energy impacts (during the engagement phase) and intense sustained loads (during the sustained push phase) under unstable conditions [1], the Rugby Union scrum has been indicated as a possible risk factor for degenerative spinal injuries for forward players, and has been associated with ~40% of all catastrophic injuries in rugby [2]. However, little is known about how these external loading conditions translate into internal stresses on the spinal structures. The aim of this study was to investigate the biomechanics of cervical spine injury during rugby activities using an integrative approach: *in-vivo* and *in-vitro* experiments combined with musculoskeletal modelling.

Methods: Three levels of analysis (Levels 1-3) were integrated. Level 1 was a biomechanical study of scrummaging (N=9 experienced rugby forwards) including motion capture (Oqus, Qualisys, Sweden), force measurement (force plates: Kistler 92876BA, Switzerland; and instrumented scrum machine, [1]), and EMG of neck and trunk muscles (Delsys Trigno, Delsys Inc, USA), carried out to assess the external kinematic and kinetic conditions acting on front row players. The subsequent phases of scrummaging, initial engagament (impact and shock absorption) and sustained push, were observed. Level 2 developed a bespoke musculoskeletal model (Rugby Model, [3]), consisting of 27 anatomical segments, 26 joints, 78 cervical muscles, and 11 torque actuators, in OpenSim (OpenSim 3.2, SimTK, USA). The Rugby Model was driven by the experimental data from Level 1 and was used to estimate joint dynamics, with a specific interest in cervical joint motions and moments. Level 3 performed an *in-vitro* laboratory experiment to study the injury mechanisms of porcine cervical spines subjected to impact loading conditions similar to those during scrummaging. Load (2 load cells: SLC41/005000, RDP Electronics Ltd, UK) and deformations caused by impacts (mass of 12.86 kg dropped from a height of 250 mm to give an impact velocity of ~2.2 m/s) were measured in a custom made impact rig, and high-speed videos (2 Fastcam SA3, Photron Europe Ltd, UK) were used to investigate the mechanisms of injury through digital image correlation (Vic-3D 2009.1.0, Correlated Solutions Inc, USA).

Results: Results from the biomechanical analysis confirmed that the load acting on the players, especially during the initial engagement, was of a considerable magnitude (~2.8 kN compression force in single-player machine scrummaging). Muscle activation patterns were affected by scrummaging conditions (e.g. machine vs. contested scrummaging; 'Crouch-touch-set' vs. 'Crouch-bind-set' sequence) and phases of the scrum (e.g. pre-engagement vs. engagement vs. sustaned push). For example, the activity of the *erector spinae* was significantly lower (in excess of 65%) in machine scrummaging than in contested scrummaging, and the activation of *sternocleidomastoid* and *upper trapezius* through pre-engagement and engagement were higher in the current 'Crouch-bind-set' technique than in the past 'Crouch-touch-set' one. The computational musculoskeletal model highlighted an antiphase change in movement and loading patterns between the upper and lower cervical levels (i.e. flexion load on the lower vertebrae and extension on the upper vertebrae), and resulted in a "flattening" of the lordotic cervical curve during the impact phase. The present findings do not provide direct evidence for injury mechanisms but seem in line with the patterns of injury that previous authors have described in relation with scrum-related neck traumas [2]. The patterns of strain, load and resulting damages on the cervical structures of the impacted porcine specimens were also similar to those clinically observed in injured players, with the caudal vertebrae (C4-C6) more prone to damages (6 out of 8 specimens) as a consequence of the impact.

Fractures resulted from tension in the vertebral bodies due to first order buckling of the cervical spine in extension. The mean maximum load in the cranial and caudal load cells was 5.8±2.0 kN and 6.0±2.1 kN and was reached at a time of 5.1±1.0 ms and 5.6±1.1 ms after impact, respectively.

Figure:



Conclusion: The proposed integrative approch provided novel and more thorough insight into how external loading conditions, muscular activity and body posture affect the internal stresses acting on the cervical spine structures. This understanding will help in elucidating injury factors related to scrummaging and represents a promising framework for future research in the area of impact-related injuries in sports. It will be further developed by including forward dynamics simulations and finite element analysis.

References: [1] Preatoni et al., BJSM, 10.1136/bjsports-2013-092938, 2014.

[2] Trewartha et al., BJSM, 10.1136/bjsports-2013-092972, 2014

[3] Cazzola et al., Proceedings of the 7th World Conference of Biomechanics (Boston, USA), 2014

Disclosure of Interest: None Declared