CERVICAL SPINE LOADING IN MISDIRECTED RUGBY TACKLES: AN INTEGRATED IN-VITRO AND IN-SILICO APPROACH

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INTRODUCTION

The mechanisms of cervical spine injury in rugby have been investigated through different methodologies, but none of them alone can fully describe the possible associations between external loads applied to the head and the internal stresses at vertebral level.

We present a combined in-*vitro* and in-*silico* approach to simulate a misdirected rugby tackle and to study the influence of head and neck position on the load acting on cervical spine.

METHODS

An anthropometric test device (ATD) (Hybrid III, Humanetics, Germany) was used to replicate the head and neck of the tackling player. The ATD was instrumented with a six-axis upper neck load cell (at C1 joint level) and was attached to a rigid frame to replicate three different neck positions (Figure 1): neutral (0°), head-down (-22°), and head-up (+22°). Simulated tackles were generated using a 40-kg punch bag making contact against the ATD at 2 different speed ranges (low: 2.0-2.5 m/s) and (high: 3.1-3.6 m/s). Ten repetitions were recorded for each speed condition and ATD orientation, 60 trials in total. Kinematics of the head/neck system was captured through a 16-camera motion capture system (Oqus, Qualisys, Sweden) at 250 Hz, whilst force and torque data were sampled at 500 Hz. Kinematics and external load data were used as input for inverse simulations in OpenSim 3.3. The OpenSim RugbyModel (https://simtk.org/projects/csibath) was scaled, and a pipeline including inverse kinematics, inverse dynamics, and joint reaction analysis was run to estimate the joint reaction forces at intervertebral joint level. Mean values of forces and moments were calculated from 10 trials in each condition. ANCOVA (covariate = bag speed) and effect sizes were used to assess the effect of head position on the loads applied to the neck.

RESULTS

ATD measurements showed that low speed tackles generated 37% lower peak impact forces (1.61 ± 0.29 kN) than high-speed tackles (2.61 ± 0.09 kN). Peak flexion/extension external moments measured during high-speed impacts trials were 54.5 ± 5.7 and 45.3 ± 4.4 Nm respectively for head-down and head-up positions, with values close to the pain thresholds reported in the literature (60 and 45 Nm for flexion and extension) [1]. The compression force was substantially higher in head-down than in neutral (by 13%) and head-up orientations (by 17%). Computer simulations showed that the cervical spine vertebrae underwent high compressive forces at all levels (> 300 N). However, anterior shear forces and flex/extension moments at C2/C3 level reached the maximal absolute values in the head-down condition (Figure 1).

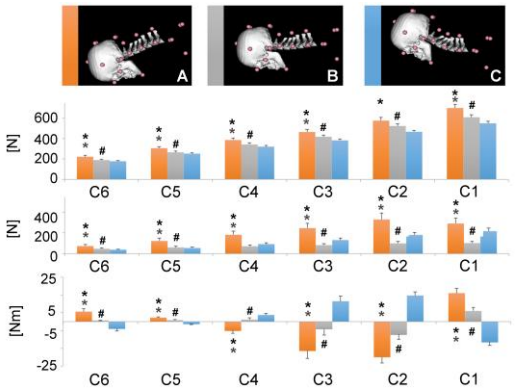

Figure 1: Intervertebral joint reaction forces, top to bottom: compression force, anteroposterior force and flexion/extension moments (mean and SD) for 6 vertebral joints (C1-C6) and for three different ATD positions showed in panel A, B and C, during high speed impacts.

DISCUSSION

The combination of high compressive forces and extension flexion moments at C2/C3 seems coherent with the hypothesis of buckling as the potential injury mechanism during head-first impacts in tackles. High repetitive stresses at this cervical spine level can cause the development of chronic degeneration pathologies as observed in asymptomatic Rugby Union players [2].

CONCLUSION

Our findings support the idea that: 1) an integrated *in vivo* and *in silico* analysis of simulated head-first impacts provides insight into how misdirected loads applied to head/neck structures distribute at the level of the individual vertebrae; and, 2) a neutral or head-up position may be preferred in the scenario of unintentional head-first impacts in rugby tackles. The 'Head-up' technique aligns with current Rugby Union coaching recommendations.

REFERENCES

1. Schmitt, KU, et al., *Trauma biomechanics an introduction to injury biomechanics*. 4:81-112, 2014
2. Castinel BH, et al., *Br J Sport Med* 44:194-199, 2010.

ABSTRACT SUBMISSION INFORMATION

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