*Citation for published version:*
Silvestros, P, Pizzolato, C, Lloyd, D, Preatoni, E, Gill, HS & Cazzola, D 2021, EMG-assisted modelling provides physiological neck muscle activation patterns during contact sport events. in *Proceedings of the 26th Conference of the European Society of Biomechanics (ESB 2021).* 26th Congress of the European Society of Biomechanics, Milan, Italy, 11/07/21.

*Publication date:*
2021

*Document Version*
Peer reviewed version

Link to publication

**University of Bath**

# EMG-ASSISTED MODELLING PROVIDES PHYSIOLOGICAL NECK MUSCLE ACTIVATION PATTERNS DURING CONTACT SPORT EVENTS

**Pavlos Silvestros[1], Claudio Pizzolato[2], David G. Lloyd[2], Ezio Preatoni[1], Harindejit S. Gill[3], Dario Cazzola[1]**

*1. Department for Health, University of Bath, Bath, United Kingdom*

*2. School of Allied Health Sciences, Griffith University, Gold Coast, Australia*

*3. Department of Mechanical Engineering, University of Bath, United Kingdom*

## Introduction

Replication and estimation of neck muscle activations during impact events is still a great challenge in biomechanics. Experimental in-vitro studies have underlined the importance of neck muscle forces as these can alter the ultimate load [1], but little is still known about how neck muscles are activated in-vivo prior to impacts. In neuromusculoskeletal modelling, EMG-assisted methods combine experimental EMG signals with optimisation procedures to generate muscle activation patterns that satisfy both experimental muscle excitation patterns and the calculated joint moments. The aim of this study is to evaluate the use of EMG-assisted neuromusculoskeletal modelling to investigate neck muscle function in preparation for collisions.

## Methods

One academy level front-row rugby player performed lab-based scrummaging and tackling using an instrumented scrum machine and tackle simulator as well as functional neck movements. Full body kinematics, neck flexors and extensors EMG, and full body MRI scans were collected.

A neuromusculoskeletal modelling pipeline that tracks experimental joint moments was used to simulate muscle activation patterns. Two neuromuscular solution modalities were assessed: static optimisation (SO) and EMG-assisted methods. An MRI-derived OpenSim model (Figure 1) was used and its muscle parameters calibrated in CEINMS [2] in two different ways: one where all the model's MTU strengths were calibrated (EMGa) and a second were 44 MTUs were prescribed with estimations obtained from segmented MRI scans (EMGaMRI).

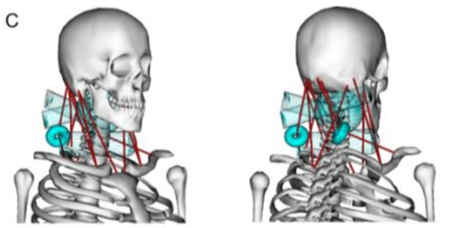


*Figure 1:The population specific 'Rugby Model'(https://simtk.org/projects/csibath) was adapted by using MRI scans of the neck region to create wrapping surfaces and update muscle parameters.*

The calibrated models were used in CEINMS to estimate muscle activations and MTU forces by tracking experimental joint moments and EMG linear envelopes in an EMG-assisted optimisation approach in remaining trials. Correlative measures across each trial were used to access model performance by comparing the results to experimental joint moments and recorded EMG values and against pure Static Optimisation.

## Results

The EMGaMRI neuromuscular solutions tracked experimental net joint moments (NJM) with the same accuracy than SO. The EMGa and EMGaMRI models successfully tracked experimental excitations for the ten MTUs corresponding to the four measured muscles (Figure 2).

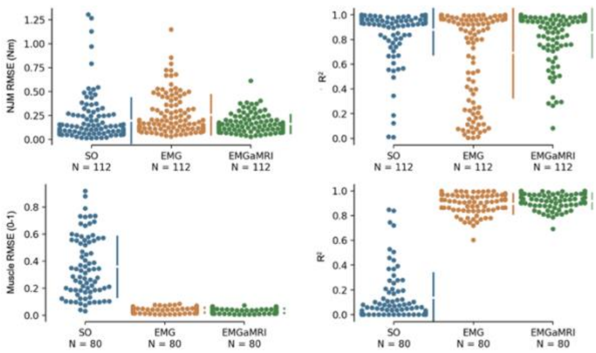


*Figure 2: Root mean square error (RMSE) and $R^2$ for NJM and muscle activation across all neck movements.*

## Conclusion

EMG-assisted models can reproduce net joint moments with MTU activations that i) track experimental EMG measurements, ii) do not saturate nor display "on-off" behaviour, iii) closely follow experimental co-contraction ratios and v) are estimated without *a priori* objective function. This is a key step forward to investigate cervical spine injury mechanisms during impact events

## References

1. Nightingale et al. (2016) *JoB*, **29(3)**:307-318
2. Pizzolato et al. (2-15). *JoB*, **48(14)**: 3929-393

## Acknowledgements

The authors would like to thank the Rugby Football Union Injured Player Foundation for funding the PhD scholarship References.