CRITICAL SHOULDER ANGLE VARIABILITY ESTIMATED WITH A CAUSAL BAYESIAN NETWORK

Pezhman Eghbali (1), Osman Berk Satir (2), Fabio Becce (3), Patrick Goetti (3), Philippe Büchler (2), Dominique Pioletti (1), Alexandre Terrier (1, 3)

1. Ecole Polytechnique Fédérale de Lausanne (EPFL), Switzerland; 2. ARTORG Center for Biomedical Engineering Research, Switzerland; 3. Lausanne University Hospital (CHUV), Switzerland

Introduction

The critical shoulder angle (CSA) is a morphological measure combining the glenoid inclination angle (GIA) and lateral extension of the acromion (LEA) [1]. High CSA has been associated to patients with cuff tear arthropathy (CTA), and low CSA to patients with osteoarthritis (OA) [2]. The CSA is increasing with age, without sex difference [3]. However, the effect of age on CSA has not been evaluated for CTA and OA separately, and more specifically the effect of age on GIA and LEA, which both influence the CSA. Hence, our objective was to evaluate the effects of age, sex, pathology, GIA, and LEA on CSA.

Methods

We included 65 CTA and 184 OA patients, and 174 normal subjects without any sign of pathology as controls (CTRL). The GIA and LEA were automatically measured from CT scans [4, 5]. GIA was defined as the angle between the scapular axis and the glenoid centerline projected onto the scapular plane. LEA was the projection of the most lateral point of the acromion on the scapular axis. CSA was the angle between the line connecting the inferior and superior borders of the glenoid, and the line connecting the inferior border of the glenoid with the most LEA. From these clinical data, we developed a causal Bayesian network to evaluate the effects of age, sex, and pathology on CSA as follows:

$$CSA_i \sim N(\mu_i, \sigma)$$
$$\mu_i = \alpha_{sex[i],pathology[i]} + \beta_{sex[i],pathology[i]}(age_i - \overline{age})$$

In addition, to evaluate the effects of GIA and LEA as follows:

$$CSA_i \sim N(\mu_i, \sigma)$$
$$\mu_i = \alpha_{sex[i],pathology[i]} + \gamma_{sex[i],pathology[i]} GIA_i + \zeta_{sex[i],pathology[i]} LEA_i$$

We used the Hamiltonian Monte Carlo (HMC) method to estimate the posterior distribution. All variables were reported as z-score (except age), with CTRL standardizations, and 89% confidence intervals (CI). The Bayesian network analysis was performed with R (RSTAN package).

Results

For CTA, the CSA increased with age for both males and females (Fig. 1). For OA, age had a slightly negative effect on CSA for males and females. For CTRL, age and sex had no effect on CSA.

For the three groups, the CSA increased with the GIA and LEA. The effects of GIA and LEA on CSA were similar for CTRL and OA, but differed for CTA, with a higher GIA effect for CTA-males and a higher LEA effect for CTA-females (Fig. 2).

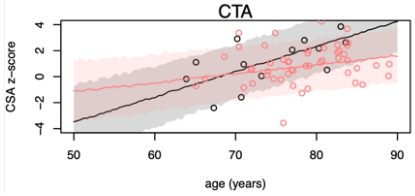

Figure 1: CSA vs age for CTA. Points (red for F and black for M) represented the real subjects and the line and the shaded area showed the mean and 89% CI of the Bayesian model.

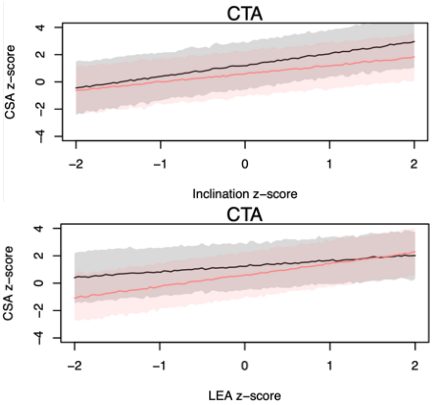

Figure 2: CSA vs GIA (top) and LEA (bottom).

Discussion

Our results showed the relative importance of age, sex, GIA, and LEA on CSA, and most importantly the different effects in CTA, compared to OA and CTRL. These results may be helpful in the early detection of shoulder pathologies, and may improve the treatments of CTA and OA, based on simple radiological measurements of the GIA and LEA.

References

1. B.K. Moor et al, Bone Joint J, 2013. 2. Zak Rose-Reneau et al, Cureus, 2020. 3. S. Gumina et al, J Orthop Traumatol, 2022. 4. Taghizadeh et al. CMBBE, 2019. 5. Terrier et al. BJJ, 2014.

Acknowledgements

This work is supported by the Swiss National Science Foundation (Grant no: 189972).