UNLOCK THE STERNOCLAVICULAR JOINT SIGNIFICANTLY AFFECTS SHOULDER KINETICS IN MANUAL WHEELCHAIR PROPULSION

Samuel Hybois[1], Joseph Bascou[1,2], François Lavaste[1,2], Hélène Pillet[1], Christophe Sauret[1]

1. Institut de Biomécanique Humaine Georges Charpak, Arts et Métiers ParisTech, Paris, France; 2. Centre d'Etudes et de Recherche pour l'Appareillage des Handicapés, Institution Nationale des Invalides, Woippy, France

Introduction

Propulsion with a manual wheelchair (MWC) is a constraining task for the upper limbs. It results that many users experience upper limbs pain or injuries, especially located at the shoulder. To understand how musculoskeletal disorders may occur, musculoskeletal modelling is an efficient approach, but it requires some hypotheses, especially when describing the kinematic chain of the upper limbs. In the literature, numerous models had considered the scapula either fixed [1] in the thorax or only tilting from angles predicted from a regression equation based on humerus elevation [2]. If some studies already showed the change in orientation of the scapula during MWC propulsion [3], few models seem to have considered the translation of the scapula, potentially altering both reconstructed kinematics from multi-body kinematics optimization (MBO) and intersegmental loads by modifying the moment arms.
The purpose of this study was to investigate the influence of unlocking the sternoclavicular joint, allowing glenohumeral joint translation, on shoulder kinetics during MWC start-up and propulsion.

Methods

Three able-bodied subjects, initiated with MWC locomotion, participated to this study. They were asked to propel an instrumented MWC (measuring both handrims forces and torques) in a motion analysis laboratory equipped with a 13 cameras optoelectronic motion capture system (Vicon System, Oxford Metrics, Oxford, UK). 30 reflective markers were fixed on the subject skin [4] allowing the joint kinematics to be obtained through a 3D linked-segment model [1] using MBO implemented in OpenSim software. Shoulder net moments were obtained using an inverse dynamics process, and expressed in the thorax orthonormal coordinate system, centered on the humeral head centre, to allow clinical interpretation.
For each subject, one start-up and one propulsion cycle were analyzed with two distinct models: first, using [1] where the scapula is fixed in the thorax frame; second, by releasing the sternoclavicular joint of the same model through two degrees of freedom (protraction-retraction and elevation-depression).

Results

Expressed in the thorax reference frame, acromion markers exhibited fore-aft translations ranging from 1.4 to 4.4 cm. Using the unlocked sternoclavicular joint model, this displacement resulted in protraction-retraction angles ranging from -13.4° to 7.6° for the whole dataset. Looking at kinetics results (Fig.1), during the push phase of the start-ups, the highest flexion and total shoulder moment were calculated. They were all higher when the clavicle was locked (+16% for both). On the contrary, they were overall lower when the clavicle was locked for steady-state propulsion cycles (+12% and +6%, respectively). For all subjects and for both tasks, the positive work per push was smaller when computed with the locked clavicle model (ranging from +6% to +61%).

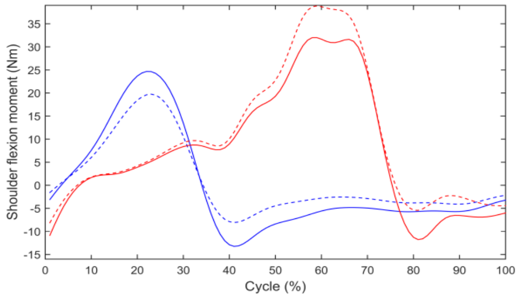

Figure 1: Shoulder flexion moment for one subject, during propulsion (blue) and start-up (red), computed with locked (plain line) and unlocked clavicle (dashed).

Discussion

The non-negligible translation of the acromion in the thorax frame, allowed by unlocking the sterno-clavicular joint, led to significant changes in the scapula kinematics. This has also significantly impacted the shoulder moments, but in a different way depending on the task performed. Besides, these changes in both shoulder kinematics and kinetics may dramatically affect muscle activation computation assessed through static optimization because intersegmental loads, muscle moment arms and muscle force-velocity curves would all be modified.
Finally, this study underlines the need of considering the clavicle protraction with MBO when studying manual wheelchair activities. Recent models with ellipsoid mobilizer [5] would be beneficial for studying this locomotion.

References

1. Saul et al, Comput Methods Biomech Biomed Eng, 18:1445-1458, 2015.
2. Holzbaur et al, Annals of Biomedical Engineering, 33(6):829-840, 2005.
3. Koontz et al, International Journal of Industrial Ergonomics, 33:237-248, 2004.
4. Hybois et al, Disability and Rehabilitation: Assistive Technology, *in press*, 2017
5. Seth et al, PLoS ONE, 11(1):e0141028, 2016.