Evaluation of scapula kinematics assessment during wheelchair sports activities

Introduction

Manual wheelchair (MWC) locomotion can lead to upper limbs injuries, especially when associated with a specific sport, such as wheelchair tennis or wheelchair basketball [1] for which overhead movements are recurrent. To understand such pathologies, shoulder kinematics assessment is critical but difficult to investigate with conventional motion analysis techniques, due to large soft tissue artefacts. A reference method, using a scapula locator device (SL) positioned on specific anatomical landmarks, has been proposed [2]. However, it has been shown to be operator-dependent and required the subject to perform the motion with a restricted range. As an alternative, some studies used a technical cluster (TC) composed of reflective markers placed on the spine of the scapula [2]. This method has been validated for functional movements, but not in ecological situations.

Research Question

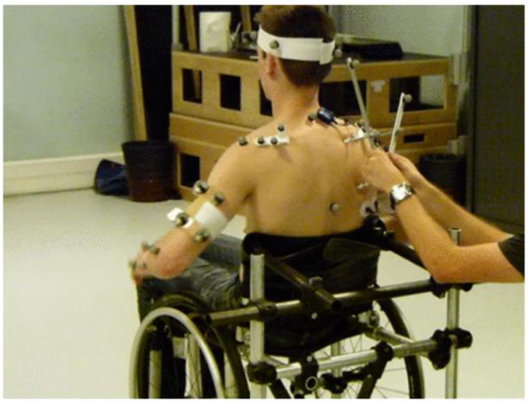
Is the assessment of the motion of the scapula with a technical cluster reliable when investigating shoulder kinematics during MWC sports activities?

Methods

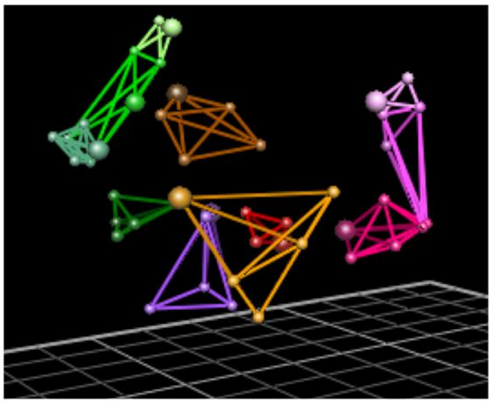
Ten subjects with various levels of disabilities participated in this preliminary study, the protocol of which received ethical approvals. During the experiments, subjects were equipped with reflective markers on the upper limbs, including a TC on the spine of the scapula, and asked to sit on a MWC ergometer and to simulate MWC propulsions, tennis serves and basketball shoots (Fig 1).

During each acquisition, a SL device was maintained by an experimenter on 3 anatomical landmarks of the scapula. Location of all markers and SL were collected simultaneously with an optoelectronic motion capture system composed of 8 cameras (Vicon system) at 100 Hz. For each acquisition, subjects started in a static position to allow calibration between the SL and TC positions. Then specific motions were performed, namely MWC propulsion, tennis serve and basketball shooting, at a lower velocity than usual for these tasks, to facilitate the scapula tracking by the experimenter who had to maintain the SL device in contact with the anatomical landmarks.

Anatomical frames of the thorax and scapula were built according to ISB recommendations [3]. The orientation of the scapula was then computed from the TC, the position of the SL device being inferred from the rigid body transformation matrix obtained during the static pose. Scapula angles were obtained using a y-x'-z" mobile-axis Euler sequence. Scapula orientation estimations were then compared to the reference



1a.



1b.

Fig 1a. Experimental session with the scapula locator device maintained on anatomical landmarks
Fig 1b. 3D reconstruction of a tennis serve, with the marker set of this study

values from the SL. Since MKO proved to prevent from bone penetration and joint dislocation and was believed to reduce soft-tissue artefacts, a further step to validate the use of a scapula TC was to reconstruct the kinematics with a custom musculoskeletal model of the upper limbs extended from [4], using multi-body kinematics optimisation (MKO) to track markers on the upper extremities (including the TC). Scapula orientation was inferred from this reconstruction.

Results

The scapula orientation obtained from the SL device for the different activities is reported on Fig.2. Basketball shooting involved the highest amplitude of scapula motion among the three activities. MWC propulsion and basketball shooting involved mainly internal/external rotation of the scapula, while tennis serves displayed mainly downward/upward rotation. Tennis serve gesture also resulted in the highest variability between subjects.

The estimation of the scapula orientation from the TC showed variations with respect to the SL device. The angular differences ranged from 1.4° (upward/downward rotation for the tennis serve) to 3.9° (anteroposterior tilt in MWC propulsion). The average distance between measured and reconstructed scapula markers was overall similar between activities and ranged from 4.5mm to 13.2 mm. Scapula orientation computed with MKO unexpectedly showed larger errors with the reference method than the estimation from the TC. The maximal angular error between the MKO method and the scapula cluster was 12° for MWC propulsion, 34° for the tennis serve and 20° for basketball shooting.

Discussion

The amplitude of scapula motion for the MWC locomotion was consistent with the literature [5]. For the tennis serve, the significant variability could be explained by the complexity of this motion and the specific strategies

	MWC propulsion	**Tennis serve**	**Basketball shooting**
Downward/upward rotation	**-10.7**° (2.3°) / **3.0**° (4.1°)	**-14.7**° (7.8°) / **21.5**° (13.1°)	**-31.1**° (14.7°) / **7.6**° (7.4°)
	1.6° (1.0°)	**2.6° (1.1°)**	**2.1° (1.3°)**
Internal/external rotation	**-25.8**° (2.0°) / **8.9**° (3.1°)	**16.0**° (20.2°) / **45.8**° (25.7°)	**-17.9**° (7.5°) / **46.0**° (6.7°)
	1.6° (0.8°)	**1.6° (0.7°)**	**1.4° (0.8°)**
Anterior/posterior tilt	**26.3**° (3.5°) / **39.3**° (3.3°)	**-14.4**° (4.6°) / **3.7**° (6.2°)	**-12.7**° (5.9°) / **2.3**° (2.0°)
	3.9° (2.2°)	**2.6° (1.0°)**	**2.4° (1.0°)**

Fig 2. Scapula orientations with respect to thorax averaged over the 10 subjects, for each activity (standard deviations between brackets), and angular root mean square differences between TC and SL estimations (in red)

chosen by each subject. To estimate scapula orientation, the TC method seemed to be efficient with respect to the SL device, because of moderate angular differences (Fig 2), that were in accordance with results from the literature in other activities [2, 6]. The potentiality of musculoskeletal modelling and MKO to improve scapula kinematics was limited by the generic dimensions of the kinematic chain, though scaled to subjects' anthropometry, which had favoured certain orientations of the scapula. The personalisation of the scapulothoracic ellipsoid parameters (centre, radii and orientation) and the clavicle length will be the next challenge to overcome this issue.

References

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