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Full Length Article

Three-dimensional kinematics of the scapula and trunk, and associated scapular muscle timing in individuals with stroke

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ABSTRACT

Poor scapulothoracic control is a risk for developing shoulder pathology, but has received little attention so far in individuals with stroke (IwS). Trunk and scapular kinematics and surface muscle activity were measured in 15 healthy controls and 18 IwS during a low and high forward flexion (FF). Group-differences in trunk and scapular kinematics were assessed during low and high FF using a t-test (independent samples). Differences in muscle onset and offset time relative to movement start (both FF tasks) were determined using a mixed model taking into account the different groups and muscles. Recruitment patterns per group and task were described based on significant differences between muscles. In IwS, earlier lower trapezius and late infraspinatus offset were found during low FF, as well as a later onset and earlier offset of serratus anterior. For low FF, significantly more trunk axial rotation was found in IwS during both elevation and lowering. During high FF, IwS showed significantly less scapular posterior tilt during elevation and more scapular lateral rotation during lowering. IwS demonstrated adaptive muscle timing with earlier initiation and late inactivation of lower trapezius and infraspinatus, possibly to compensate for a late activation and early deactivation of the serratus anterior and to establish as such the correct pattern of scapulothoracic movement.

1. Introduction

The onset of hemiparesis after stroke adversely affects normal joint alignment, movement patterns and muscle activation patterns of the shoulder complex through mechanisms including muscle weakness, muscle spasticity and loss of voluntary motor control (Ryeson & Levit, 1997). These changes negatively influence the stability of the shoulder complex and thereby contribute to the development of pathologies leading to musculoskeletal shoulder pain or dysfunctions (e.g. tendinopathy of the rotator cuff, subluxation of the humeral head, adhesive capsulitis) (Ryeson & Levit, 1997). Shoulder dysfunctions after stroke have a reported prevalence between 48% and 77% and strongly impact on daily life functioning of these patients (Chae et al., 2007; Lawrence et al., 2001; Persson, Parziali, Danielsson, & Sunnerhagen, 2012). From early stages in rehabilitation, adequate strategies to prevent or reduce shoulder function losses or shoulder pain are thus imperative. However, this can only be attained via a meaningful and comprehensive assessment.

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Since correct shoulder function is related to scapulothoracic functioning, a shoulder assessment should include the scapulothoracic joint. During arm elevation in healthy persons, the scapula moves toward lateral rotation and posterior tilting, and depending on the elevation plane, both scapulothoracic protraction and retraction have been reported (Fig. 1A) (Ludewig et al., 2009). To achieve such a three-dimensional (3D) character of scapulothoracic movement, coordinated muscle activation of scapulothoracic stabilizers is required, i.e. the serratus anterior, and the upper and lower trapezius (Ludewig & Cook, 2000). Furthermore, spinal posture is also associated with scapulothoracic motion and muscle activity during humeral elevation (Nagai et al., 2013). Hence, advanced assessment methods like 3D movement analysis with synchronized electromyography (EMG) might offer further insights into the scapulothoracic joint in individuals with stroke (IwS).

Studies thus far reported discrete but inconclusive alterations in 3D scapulothoracic joint angles post-stroke (Hardwick & Lang, 2011a,b; Meskers, Koppe, Konijnenbelt, Veeger, & Janssen, 2005; Niessen et al., 2008; Robertson, Roche, & Roby-Brami, 2012; Rundquist, Dumit, Hartley, Schultz, & Finley, 2012). Niessen et al. (2008) reported increased lateral rotation in IwS with shoulder pain compared to controls, whereas Hardwick and Lang (2011b) reported only a trend toward a decreased scapular lateral rotation in IwS. Comparing muscle activation between IwS with and without shoulder pain has shown early activity of lower trapezius and delayed inactivity of serratus anterior in those IwS without shoulder pain (De Baets, Jaspers, Janssens, & Van Deun, 2014). Furthermore, during a dynamic abduction, alterations in muscle recruitment patterns and onset time of the middle deltoid and upper trapezius of the hemiplegic arm have also been reported (Avila, Romaguera, Oliveira, Camargio, & Salvini, 2013). Unfortunately, no evidence exists on the combined assessment of 3D scapular kinematics and muscle timing post-stroke, or on the impact of spinal posture on scapular muscle timing during arm elevation. In healthy controls, alterations in spinal posture have already been shown to contribute to changes in scapular muscle activity, and in scapular movement during arm elevation (Nagai et al., 2013; Yamauchi et al., 2015). This emphasizes the importance of a combined 3D-EMG assessment to study the role of the scapulothoracic joint and trunk with respect to upper limb (dys)-functions (i.e. decreased range of motion) in IwS.

Here, the hypothesis that alterations in trunk and scapular kinematics in IwS are associated with changes in scapulothoracic muscle timing, is investigated. Therefore, trunk and scapulothoracic kinematics and EMG are compared between IwS and age-matched healthy controls during an elevation task.

2. Methods

2.1. Participants

IwS without shoulder pain were recruited from the University Hospital Pellenberg (Belgium) and were considered eligible for participation in case they: (1) were at least 6 weeks after a first time stroke (cortical or subcortical lesion); (2) had mild to moderate upper limb motor impairment (score $\geqslant$ 30/66 on the Fugl-Meyer upper limb motor part (Platz et al., 2005)); and (3) were able to perform at least 45° of active humerothoracic forward flexion (FF, measured with goniometry). Age-matched healthy controls without self-reported shoulder pain were recruited via family and relatives. For all participants, following exclusion criteria were applied: (1) body mass index >28 kg/m^2; (2) inability to understand the instructions; (3) known history of shoulder and/or neck pain or discomfort in the last 6 months or the last 6 months prior to stroke; (4) an event of shoulder dislocation, fracture or surgery during life time; (5) other systemic and/or neurologic diseases. All IwS received standard care and physiotherapy, attuned to their specific needs. An overview of participants' characteristics is given in Table 1. No significant differences between groups were found for age, gender, or hand dominance ($p > 0.05$). All participants gave informed consent prior to study participation, as approved by the Ethical Committee of the University Hospital Leuven (Belgium).

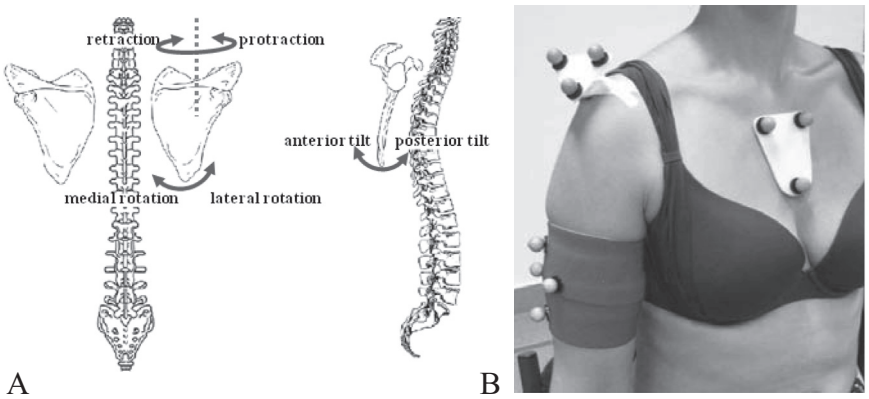

Fig. 1. Scapulothoracic kinematics (A) and cluster placement at the sternum, acromion and upper arm (B).