Journal of Electromyography and Kinesiology 24 (2014) 165–171

Contents lists available at ScienceDirect

Journal of Electromyography and Kinesiology

journal homepage: www.elsevier.com/locate/jelekin

Anticipatory postural adjustments during sitting reach movement in post-stroke subjects

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ARTICLE INFO

Article history:
Received 21 November 2012
Received in revised form 22 September 2013
Accepted 3 October 2013

Keywords:
Anticipatory postural adjustments
Stroke
Sitting
Movement velocity reach movement
Electromyography

ABSTRACT

The study assessed the effect of velocity of arm movement on anticipatory postural adjustments (APAs) generation in the contralateral and ipsilateral muscles of individuals with stroke in seating. Ten healthy and eight post-stroke subjects were studied in sitting. The task consisted in reaching an object placed at scapular plane and mid-sternum height at self-selected and fast velocities. Electromyography was recorded from anterior deltoid (AD), upper (UT) and lower trapezius (LT) and latissimus dorsi (LD). While kinematic analysis was used to assess peak velocity and trunk displacement. Differences were found between the timing of APAs on ipsi and contralateral LD and LT in both movement speeds and in ipsilateral UT during movement of the non-affected arm at a self-selected velocity. A delay on the contralateral LD to reach movement with the non-affected arm at fast velocity was also observed. The trunk displacement was greater in post-stroke subjects. Individuals with stroke demonstrated a delay of APAs in the muscles on both sides of the body compared to healthy subjects. The delay was observed during performance of the reaching task with the fast and self-selected velocity.

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1. Introduction

The Central Nervous System (CNS) can counteract the expected mechanical effects of the perturbation induced by movement in a feedforward manner through anticipatory postural adjustments (APAs) (Aruin and Shiratori, 2003). The APAs involve changes in the background muscle activity prior to voluntary movement (Shiratori and Aruin, 2004; Bonnefoy et al., 2009). Their main goal is to assist motor performance in order to minimize the pertrubation of balance. The APAs can be characterized by spacial, quantitative and temporal parameters. The temporal parameter has been vastly explored in studies related to postural control mechanisms and is related to the timing of muscular activation (Van Der Fits et al., 1998). The "time window" of the APAs begins 100 ms (ms) before till 50 ms after the beginning of prime mover activity (Yoshida et al., 2008). Indeed, it is possible to identify and characterize the APAs through surface elctromyography (sEMG).

The generation of APAs can be challenging in persons with neurologic disorders such as stroke (Aruin, 2002). Following a stroke in the MCA territory, damages can occur in the internal capsule, (Miyai et al., 1999), leading to the cortico-pontine networks impairment which involves the output of supplementary motor area related with the temporal aspect of APAs. Current evidence suggests that these subjects have a delay on APAs in the paretic side compared to healthy subjects (Slijper et al., 2002; Dickstein et al., 2004). However, the unilateral nature of APAs impairment is doubtful due to the bilateral vs. ipsilateral disposal of neuronal systems to axial and trunk muscles (Dickstein et al., 2004). Due to the bilateral impairment of APAs, post-stroke subjects may not be prepared for the environmental changes and for the constant disturbances of the center of mass during voluntary movement, which affects their functionality. Nonetheless, it still remains unclear whether the APAs of post-stroke individuals are bilaterally impaired during daily activities such as the reach movement.

Beyond neurologic diseases other factors interfere in APAs such as posture and several biomechanical factors like the inertia of the moving segments, velocity of movement and initial and final position of the body (Aruin and Shiratori, 2003). In fact, APAs seems to be larger when the velocity of the arm movement is higher (Yoshida et al., 2008). Furthermore, according to Mochizuki et al. (2004), the increase of velocity of the arm movement leads to an increase of the APA amplitude accompanied by a small change in

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http://dx.doi.org/10.1016/j.jelekin.2013.10.001

the APA timing. Nevertheless, the velocity' influence on the timing of APAs remains controversial and understudied especially in respect to post-stroke subjects.

Regarding post-stroke subjects, the most frequent postural basis for reaching activities is the sitting position. In sitting, the inertial forces are lower and the center of mass is closer to the base of support that is substantially larger compared to the standing position. Therefore, keeping the projection of the center of mass within the limits of the base of support (Aruin and Shiratori, 2003), is less challenging, which could lead to a decrease or even absence of APAs (Yoshida et al., 2008). Prior to arm movement, the CNS generates APAs in the postural trunk muscles, which is intended to control the flexor moment and trunk orientation (Cirstea and Levin, 2000; Lee et al., 2009). However, post-stroke subjects exhibit an excessive trunk displacement while performing a reach movement, which could result from APAs impairment or elbow extension, shoulder flexion and adduction impairment (Levin et al., 2002; Robertson and Roby-Brami, 2011).

The aim of the present study was to investigate the effect of changes in the velocity of reach movement performed in seated position on the APA generation in individuals post-stroke. We hypothesized that the APAs in individuals with stroke will be delayed in the muscles on the contralateral and ipsilateral sides of the body as compared to healthy controls regardless of the velocity of the reaching movement. We also hypothesized that trunk movements associated with performance of the reaching will be larger in individuals with stroke compared to healthy controls.

2. Methods

2.1. Sample

The sample ($n = 18$) of this cross-sectional observational study consisted in 2 groups: group 1 included healthy controls ($n = 10$) and group 2 consisted of individuals with stroke ($n = 8$). Group 1 included 3 males and 7 females (age 51.5 ± 5 yrs; height 1.64 ± 0.085 m; weight 72.5 ± 11.1 kg; medina ± interquartil deviations). Regarding arm dominance in group 1, 1 participant was left-handed and 9 were right-handed. Inclusion criteria for group 1 were: subjects older than 45 years, and exclusion criteria were the presence of uncorrected visual deficits, neuromusculoskeletal pathologies and/or pain lasting more than three months on the neck and/or shoulder. Group 2 involved two females and six males (age of 60.5 ± 5 yrs). Table 1 provides a description of the sample. Post-stroke subjects were recruited from 3 health institutions of Porto and Braga (northern Portugal) regions. The lesion was restricted to the territory of the MCA confirmed by computed tomography scans. Inclusion criteria involved: the presence of subcortical lesions after stroke in the MCA territory occurred at least 6 months; ability to remain sitting without support; active range of motion at least 15° on shoulder and elbow of the affected arm; and capacity to understand and follow simple instructions. Exclusion criteria included the presence of Parkinson disease, previous stroke, uncorrected visual deficits, apraxia and hemineglect; neuromusculoskeletal pathologies and pain lasting more than three months on the neck and/or shoulder and score below 25 in the Mini Mental Test.

2.2. Instruments

Performance of activity of daily living was assessed using the Modified Barthel Index validated for the Portuguese population by Lima et al. (1998) (Santos et al., 2005).

Surface electromyography (sEMG) was recorded through two bioPLUX® (Plux, Portugal) devices with a sampling frequency of 1000 Hz, common mode rejection ratio 110 dB, input impedance greater than 100 Moms and analog channels with 12 bits. For sEMG, bipolar sensor configuration was selected and child ECG electrodes were used. The electrodes were Ag/AgCl, circular, with 10 mm of diameter and auto-adhesive (Hermens et al., 2000). The sEMG signals were analyzed through the AcqKnowledge Analysis Software version 3.9 (Biopac Systems, Inc., Goleta, USA).

Skin impedance was measured using the Noraxon® Impedance Checker system (Noraxon, Scottsdale, Arizona).

Kinematics was recorded using four-camera Qualisys Motion Capture System (sampling frequency: 100 Hz) and analyzed using Qualisys Track Manager (QTM) Software (Qualisys, Sweden). Kinematic analysis with QTM was synchronized with the sEMG.

2.3. Procedures

The assessment was performed in a sitting position without trunk support and the feet flat on the floor. The seat height was adjusted based on each participant's lower limb length, measured in standing position from the lateral line of the knee joint to the ground. The subjects were seated with the 75% of the thigh length (measured from the lateral knee-joint line to the greater trochanter) supported on the seat and knees and hips at approximately 90° of flexion, shoulders in a neutral position, and hands resting on the hips.

After the skin preparation and impedance measurement, the electrodes were placed parallel to the muscle fibers over the anterior deltoid (AD) (prime mover), upper trapezius (UT), lower trapezius (LT), and latissimus dorsi (LD) in accordance with SENIAM recommendations (Fig. 1). The inter-electrode distance was 20 mm (Hermens et al., 2000). Regarding the LD, the electrodes were placed obliquely 4 cm below the inferior angle of the scapula, more precisely at the muscular curve at the T2 level and along the line from the posterior axillary fold to the spinous process of S2 (Swinnen et al., 2012). Reference electrodes were placed above the olecranon. All the electrodes were connected to two bioPLUX® devices. Reflective markers were placed over the radial styloid

Table 1
Demographic characteristics of post-stroke participants.

Subject	Age (years)	Gender[a]	D[b]	Weight (kg)	Height (m)	Time from stroke (years)	Stroke type	Side of hemiparesis	Barthel Index
1	50	F	R	71	1.57	3	Ischemic	L	89
2	65	M	R	105	1.69	2	Ischemic	R	92
3	62	M	R	82	1.70	4	Ischemic	L	82
4	58	M	R	85	1.73	2	Ischemic	L	39
5	69	M	R	80	1.71	1	Ischemic	L	96
6	63	M	R	104	1.79	1.5	Ischemic	L	97
7	59	M	R	72	1.65	10	Ischemic	L	89
8	54	F	R	80	1.58	4	Ischemic	R	84

[a] Gender: F (female); M (male).
[b] Previous dominant limb: L (left); R (Right).

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