Journal of Electromyography and Kinesiology 30 (2016) 151–160

Contents lists available at ScienceDirect

Journal of Electromyography and Kinesiology

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

Torque steadiness and muscle activation are bilaterally impaired during shoulder abduction and flexion in chronic post-stroke subjects

Gabriela Lopes Santos [a,*], Luisa Fernanda García-Salazar [a,b], Matheus Bragança Souza [a], Ana Beatriz Oliveira [a], Paula Rezende Camargo [a], Thiago Luiz Russo [a,*]

[a] Department of Physiotherapy, Federal University of São Carlos (UFSCar), São Carlos, SP, Brazil
[b] Physical Therapy Program, School of Medicine and Health Science, University of Rosario, Bogotá, D.C., Colombia

ARTICLE INFO

Article history:
Received 30 March 2016
Received in revised form 30 June 2016
Accepted 5 July 2016

Keywords:
Paresis
Sensorimotor feedback
Upper extremity
Proprioceptive feedback

ABSTRACT

Objective: To characterize sensorimotor control and muscle activation in the shoulder of chronic hemiparetic during abduction and flexion in maximal and submaximal isometric contractions. Furthermore, to correlate submaximal sensorimotor control with motor impairment and degree of shoulder subluxation.

Methods: Thirteen chronic hemiparetic post-stroke age-gender matched with healthy were included. Isometric torques were assessed using a dynamometer. Electromyographic activity of the anterior and middle deltoid, upper trapezius, pectoralis major and serratus anterior muscles were collected. Variables were calculated for torque: peak, time to target, standard deviation (SD), coefficient of variation (CV), and standard error (RMSE); for muscle activity: maximum and minimum values, range and coefficient of activation. Motor impairment was determined by Fugl-Meyer and shoulder subluxation was measured with a caliper.

Results: Paretic and non-paretic limbs reduced peak and muscle activation during maximal isometric contraction. Paretic limb generated lower force when compared with non-paretic and control. Paretic and non-paretic presented higher values of SD, CV, RMSE, and CV for prime mover muscles and minimum values for all muscles during steadiness. No correlation was found between sensorimotor control, motor impairment and shoulder subluxation.

Conclusion: Chronic hemiparetic presented bilateral deficits in sensorimotor and muscle control during maximal and submaximal shoulder abduction and flexion.

1. Introduction

Stroke is the second leading cause of death and the first of disability in the adult population (Feigin et al., 2014). Although spontaneous motor recovery can be observed in hemiparetic subjects, 50–70% of these individuals present residual deficits in the upper extremities even 2–4 years post-stroke (Hunter and Crome, 2002). These deficits may be related to sensorimotor control disruption that includes impairments in strength (Andrews and Bohannon, 2000; Avila et al., 2013; Colebatch and Gandevia, 1989; Jung et al., 2002; McCrea et al., 2003; Turner et al., 2012), proprioception (Niessen et al., 2008; Santos et al., 2015), coordination (Murphy et al., 2006), and muscle synergies (Rueda et al., 2012).

A good method to evaluate sensorimotor control during activities of the upper limbs is the steadiness assessment (Chow and Stokic, 2011). This test evaluates the muscle's ability to maintain and modulate submaximal torques over time, which affects the performance of activities of daily living (Chow and Stokic, 2011; Lodha et al., 2010). Some studies have identified that post-stroke individuals present deficits in sensorimotor control during submaximal activities of both lower (Chow and Stokic, 2011, 2013, 2014) and upper extremities (elbow, wrist, and fingers) (Lodha et al., 2013; Lodha et al., 2010; Naik et al., 2011), which are correlated with the degree of motor impairment (Lodha et al., 2010).

Likewise, understanding muscle activation patterns is also important to clarify the sensorimotor deficits present in this population, since fluctuations in force are related to alterations in muscle activation (Graves et al., 2000; Shinohara et al., 2003). During sustained submaximal voluntary contractions of wrist and elbow

* Corresponding author at: Laboratório de Pesquisa em Fisioterapia Neurológica, Departamento de Fisioterapia, Universidade Federal de São Carlos (UFSCar), São Paulo, Rodovia Washington Luís, Km 235, Zip Code 13565-905, Brazil. (G.L. Santos).
E-mail address: gabrielalsantos@hotmail.com (G.L. Santos).

http://dx.doi.org/10.1016/j.jelekin.2016.07.003
1050-6411/

flexion, McNulty et al. (2014) observed that hemiparetic subjects (time post-stroke of 3–168 months) presented bilateral deficits in firing rate, discharge variability (coefficient of variation) and dynamic range of mean motor unit firing rates.

Appropriate sensorimotor control involves processing and integrating intact information from all of the sensory systems, including somatosensory systems. For example, proprioception has been reported as an important component in feedback and feedforward control during motor action (Riemann and Lephart, 2002a,b; Roijezon et al., 2015). In this sense, previous studies observed hemiparetics post-stroke presented bilateral proprioceptive deficits (Niessen et al., 2008; Santos et al., 2015). Furthermore, according to Santos and coworkers (Santos et al., 2015), higher the degrees of shoulder subluxation were correlated with higher absolute errors concerning the joint position sense (proprioceptive deficit). Both central and peripheral components seem to affect sensorial perception, processing and integration in post-stroke subjects, thus, it is reasonable to suppose that sensorimotor control, measured by steadiness assessment, might be bilaterally affected in shoulders of chronic post-stroke individuals and correlated with the degree of subluxation.

Although previous reports have already described bilateral deficits of upper limbs in post-stroke subjects, such as muscle weakness and altered sensibility, coordination and muscle synergy (Andrews and Bohannon, 2000; Avila et al., 2013; Colebatch and Gandevia, 1989; Jung et al., 2002; McCrea et al., 2003), no information is available about the ability of proximal upper limb musculature to generate and to sustain submaximal forces. This ability is important to provide stability during functional situations, for example for reaching objects. Steadiness test has been used to evaluate dexterity in different populations, such as athletes (Saccol et al., 2014; Zanca et al., 2013), individuals with Parkinson's disease (Robichaud et al., 2005; Rose et al., 2013), older adults (Chung-Hoon et al., 2016; Holmes et al., 2015) and cerebral palsy (Bandholm et al., 2009), demonstrating its reliability and validity. Evaluating the ability to generate and maintain submaximal torque over time, this study attempted to mimic functional situations, when proximal upper limb muscle activation and maintenance are required, for example for reaching objects. In addition, electromyography can indicate how shoulder control is disturbed during these tasks, showing evidence of neural strategies for sensorimotor control of proximal musculature of the shoulder.

Therefore, the main purpose of this study was to evaluate the changes in sensorimotor control and muscle activation in the shoulder complex of chronic hemiparetic post-stroke individuals during abduction and flexion in two different situations: (1) maximal voluntary isometric contractions and (2) submaximal isometric contractions with target torque. A secondary purpose was to determine whether there is a correlation between sensorimotor performance and motor impairment, and shoulder subluxation grade. The following hypotheses were tested: (1) reduced force generation and accuracy, increased variability, and altered muscle activation would be observed in the paretic and non-paretic sides when compared to control; (2) sensorimotor performance would be negatively correlated with motor impairment, and shoulder subluxation grade.

2. Methods

The cross-sectional study was approved by the Human Research Ethics Committee of the University (report #112.551/2012), pursuant to National Health Council Resolution 466/2012. The sample size was calculated from the first ten subjects evaluated in this study (five hemiparetics and five healthy control subjects). The root mean square error of submaximal torque during flexion shoulder was the main outcome measure. G.Power 3.1 software was used and a power of 0.80 and 5% of significance was set.

2.1. Participants

Participants aged 40–75 years were recruited from the local community. The recruitment period was from January to July 2014. The study procedures were explained to all participants, and written informed consent was obtained from all of them. The following inclusion criteria were considered for the Hemiparetic Group (HG): 6 months or longer post-stroke; one or more ischemic strokes in the same hemisphere determined by magnetic resonance imaging (MRI); spasticity score $\leqslant 2$ on the Modified Ashworth Scale (MAS); ability to perform shoulder flexion and abduction $\geqslant 45°$ voluntarily; and adequate control of the trunk confirmed by the individual's ability to maintain a sitting posture without the support of the trunk and arms for one minute. Because there is no consensus in the literature about sensorimotor impairments due to type of stroke, this study considered just ischemic etiology.

The Control Group (CG) consisted of healthy subjects (Booth and Lees, 2006) matched for gender and age with individuals in the HG and with a score of $\geqslant 9$ in the Basal Physical Activity Questionnaire, indicating that they were not sedentary (Baecke et al., 1982; Thorp et al., 2011). Sedentary behavior can be deleterious for skeletal muscle constitution and also for neuromuscular performance (Bogdanis, 2012). The participants from both groups presented Mini-Mental State Examination scores in accordance with their personal educational levels (Brucki et al., 2003; Vilaro et al., 2007).

The exclusion criteria for both groups were as follows: severe cardiovascular diseases (heart failure, arrhythmias, angina pectoris, and acute myocardial infarction); neurological or orthopedic diseases; cognitive or communication impairments; any history of joint or muscle injuries of the shoulder complex or cervical joints (fractures or surgery); shoulder pain during the assessments; body mass index >28 kg/m^2; and visual deficits. For the HG, individuals with other neurologic diseases, acute stroke, hemorrhagic stroke or any injury to the occipital lobe, brainstem, or cerebellum were also excluded. For the CG, individuals with unstable shoulders were excluded either if sulcus sign was present or apprehension test was positive (Wilk et al., 1997).

2.2. Clinical assessment

Participants were first submitted to an interview that included collection of personal data, physical examination and functional investigation. The clinical assessment was conducted by a single evaluator. The upper extremity motor impairment of the hemiparetic participants was assessed by the Fugl-Meyer Assessment (FMA) (Maki et al., 2006). They were also assessed for the presence of shoulder subluxation, which was quantified by determining the distance between the lateral edge of the acromion and the upper edge of the humeral head using a caliper. Based on the distance, the subluxation was graded as 0, 1+, 2+ or 3+ for distances of <0.5 cm, 0.5 to 1 cm, 1–2 cm, or >2 cm, respectively (Boyd et al., 1993). This measurement was performed in the two-day evaluation (clinical assessment and peak torque/steadiness torque) by the same evaluator in order to perform the reliability of intra-rater measure. The reliability for the caliper subluxation measure was determined by calculating Intraclass Correlation Coefficient (ICC) and it was 0.97. Finally, both groups were assessed for manual preference by the Edinburgh Handedness Inventory (Oldfield, 1971). For HG, manual preference before stroke was considered.