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Short communication

Cocontraction measured with short-range stiffness was higher in obstetric brachial plexus lesions patients compared to healthy subjects

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ABSTRACT

We suggest short range stiffness (SRS) at the elbow joint as an alternative diagnostic for EMG to assess cocontraction.

Elbow SRS is compared between obstetric brachial plexus lesion (OBPL) patients and healthy subjects (cross-sectional study design). Seven controls (median 28 years) and five patients (median 31 years) isometrically flexed and extended the elbow at rest and three additional torques [2.1,4.3,6.4 N m] while a fast stretch stimulus was applied. SRS was estimated *in silico* using a neuromechanical elbow model simulating the torque response from the imposed elbow angle.

SRS was higher in patients (250 ± 36 N m/rad) than in controls (150 ± 21 N m/rad, $p = 0.014$), except for the rest condition. Higher elbow SRS suggested greater cocontraction in patients compared to controls. SRS is a promising mechanical alternative to assess cocontraction, which is a frequently encountered clinical problem in OBPL due to axonal misrouting.

1. Introduction

Obstetric Brachial Plexus Lesion (OBPL) concerns a closed traction injury of the brachial plexus during birth, with an incidence of 0.5–2.6 per 1000 live births (Walle and Hartikainen-Sorri, 1993). Twenty to thirty percent of cases have a permanent functional deficit (Pondaag et al., 2004). Functional muscle recovery following OBPL depends on the number of outgrowing motor axons that reinnervate muscle fibres, on how many axons are misrouted to the wrong muscles (van Dijk et al., 2001, 2007), and on aberrant central motor programming (Anguelova et al., 2016). Misrouting occurs when a regenerating axonal sprout, which may also be one of several branches, elongates into a basal lamina tube different from the original one (de Ruiter et al., 2013). This may lead to the innervation of an antagonistic muscle and cocontraction. Cocontraction causes joint stiffness, resulting in serious functional problems in OBPL, possibly more so than primary muscle weakness (van Dijk et al., 2007). Cocontraction can be assessed qualitatively using electromyographical (EMG) techniques (Anguelova et al., 2014), but quantifying its contribution to motor impairment is difficult due to potential EMG cross-talk (van Vugt and van Dijk, 2001). Cross-talk is the unintended registration of neighbouring muscle activity. Clinical assessment (e.g. joint range of motion, muscle strength) cannot distinguish between weakness of one muscle and cocontraction of its antagonist.

'Short range stiffness' (SRS) is a promising alternative representing the state of the mechanical system including the cocontraction and/or muscle weakness. SRS, i.e. the ratio of a change in torque over change in angle, is assigned to the elastic properties of the cross-bridges in the muscle fibres (Campbell and Lakie, 1998). Both the agonist and antagonist muscles exhibit stiffness and so the total joint SRS is the sum of their stiffness ($SRS_{joint} = SRS_{agonist} + SRS_{antagonist}$). The actual torque is the difference between agonist and antagonist torque ($T_{joint} = T_{agonist} - T_{antagonist}$) (van Eesbeek et al., 2010). To obtain the same net flexion torque as healthy individuals, patients with biceps-triceps cocontraction will require an increased overall activation to overcome triceps cocontraction, leading to higher elbow stiffness (Fig. 1). Hence, the aim of this pilot study was to quantify elbow SRS and compare

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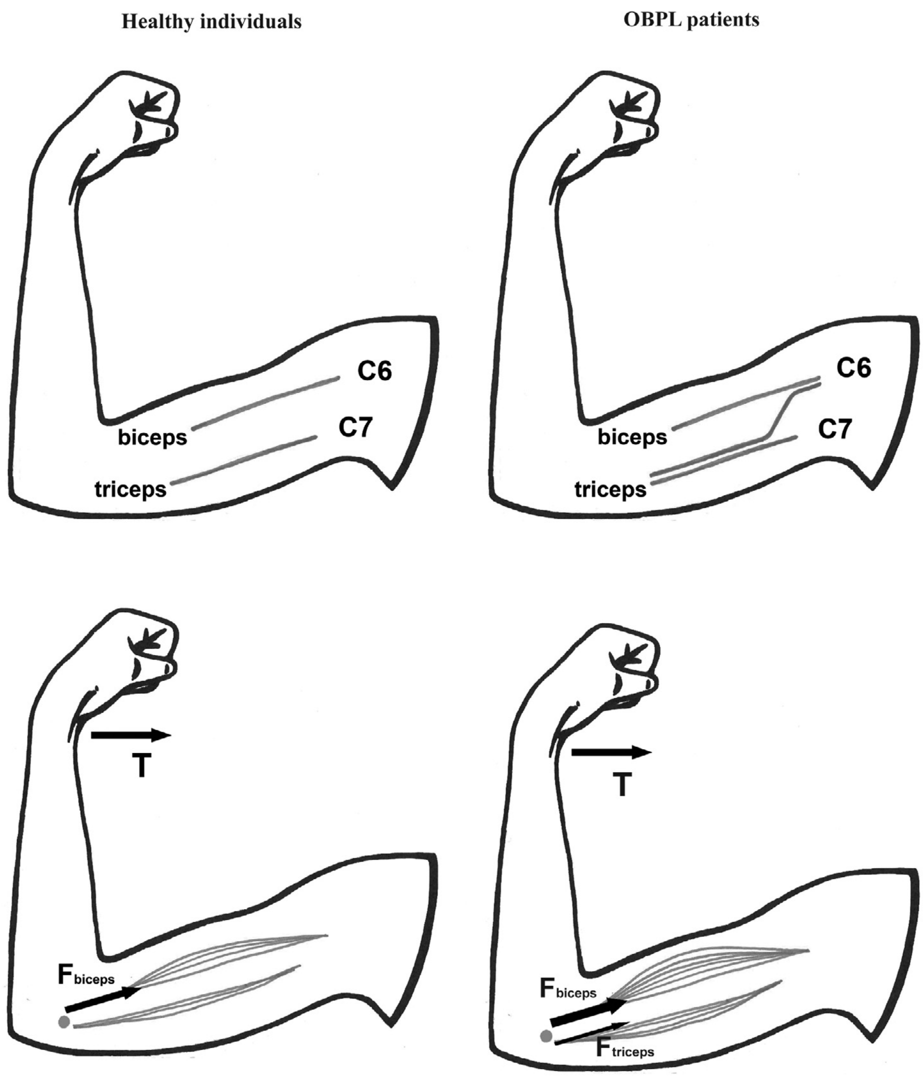

Fig. 1. For the same net flexion torque, obstetric brachial plexus lesion (OBPL) patients (right) with motor misrouting which causes increased triceps activation would have to activate the biceps more than healthy individuals (left). Top: Difference in innervation by nerve roots C6 and C7. (Not shown: theoretically also possible cross-innervation from nerve root C7 to biceps muscle in OBPL.) Bottom: Difference in muscle activation, indicated by the size of the muscles and the arrow thickness (F – force, T - torque). (Not shown: there is some triceps activation in healthy individuals, presumably contributing to joint stability.) In the case of absent misrouting we expect that SRS in patients for a certain torque would be within the healthy individuals range and activation ratio (AR) would be high (i.e. close to 1 as in healthy individuals). In the case of misrouting, SRS in patients would be higher than in healthy individuals and AR would be low (i.e. close to 0). In the case of paresis, certain torque levels may not be reached and SRS in patients for the lower torques are normal compared to healthy individuals and AR will be low with a tendency towards zero due to an unfavourable signal-to-noise ratio. Thus, SRS can potentially distinguish between normal function, cocontraction due to misrouting, and paresis.

it between OBPL patients and controls and we hypothesize that SRS will be higher in patients.

2. Materials and methods

Five adult patients with OBPL, recruited from the Dutch Erb's Palsy Association and earlier research projects of the Leiden University Medical Centre (LUMC) Rehabilitation Department, and seven controls participated. Exclusion criteria were brachial plexus surgery and any other relevant neuromuscular or joint disease. All patients had participated in a previous study (Anguelova et al., 2014). Patients were included when they were able to flex and extend the arm against gravity with a muscle strength of at least grade 3 (Medical Research Council & Committee, 1954). Patients were included who had suffered a traction lesion corresponding to at least the spinal nerves C5, C6 and C7. The study was approved by the Medical Ethics Committee of the LUMC. All participants provided written informed consent.

We adapted the wrist perturbator used by van Eesbeek and colleagues for elbow use (Fig. 2) and adapted the experimental protocol with some alterations described below (van Eesbeek et al., 2010). All variables were transformed in coordinates centred on the elbow (Appendix A). Participants were requested to generate four elbow torque levels in random order for flexion as well as extension, of 0 N m (i.e. relaxed muscles) and on average 2.1, 4.3 and 6.4 N m, depending on arm length. A ramp-and-hold rotation (0.15 radians, 4 radians/s) was automatically started when the difference between the torque generated by the participants and the target level was smaller than 2.5% for 0.5 s. A 15 s rest period was included after each stimulus to prevent fatigue and thixotropic force reduction, a phenomenon affecting resting tension due to earlier muscle use (Campbell and Lakie, 1998). Strain gauge signals were sampled at 5 kHz and low-pass filtered (50 Hz, 3rd order Butterworth filter). SRS was estimated during the first 0.04 s of torque, preventing stretch reflexes to affect the measurements, (Appendix B) (Anguelova, 2012) resulting in 32 trials (4 torque