PATHOLOGICAL MUSCULAR COACTIVATION HINDERS EFFECTIVE MOVEMENT EXECUTION: EXEMPLARY ANALYSIS IN CHILDREN AFFECTED BY BRACHIAL PLEXUS LESION

J. Gooding¹, L. Meinecke¹, G. Rau², J. Bahm³ and C. Disselhorst-Klug¹
¹Department of Rehabilitation & Prevention Engineering, Institute of Applied Medical Engineering, RWTH Aachen University, Aachen, Germany
²Helmholtz-Institute for Biomedical Engineering, Aachen, Germany
³Franziskus Hospital, Aachen, Germany
email: gooding@hia.rwth-aachen.de, web: www.hia.rwth-aachen.de

SUMMARY
Pathological coactivation of antagonistic muscles hinders effective movement execution. In order to evaluate the quality of the performed movements, precise information regarding the muscular coordination patterns involved is required. However, the inherent occurrence of crosstalk in surface electromyography (sEMG) data introduces uncertainty differentiating the actual presence of coactivation from the effects of crosstalk while evaluating muscular coordination patterns. A methodology has been developed by which, an individual Crosstalk Risk Factor (CRF) and a Confidence value for Coactivation (CCA) are calculated, providing a means for the quantification of the individual likelihood of occurrence of coactivation. The proposed methodology was applied to the analysis of movement execution on patients affected by obstetric brachial plexus lesion, proving itself as a valuable tool supporting medical diagnosis in pathological conditions affecting muscular coordination.

INTRODUCTION
The brachial plexus is a nerve network that innervates the muscles and skin of the chest, shoulder, arm and hand. In the case of obstetric brachial plexus lesion the motor and sensory pathways are generally disturbed following an avulsion or rupture of the brachial plexus complex during traumatic birth. Human movement is generally initiated by muscular activation, through which a net moment is induced on the involved joints, resulting in a rotation around their anatomical axes. In the case of plexus injury the muscular coordination pattern is often disturbed by a pathological coactivation of antagonistic muscles, resulting in unphysiological joint moments and incorrect movement patterns in the upper extremity. Thereby precise information about the quantitative extent and a diagnosis of the actual cause of the limitation represent vital factors for a successful treatment [1,2]. The evaluation of muscular coordination is therefore of great importance in the diagnosis of movement impairments [3]. An established technique to gather this information is bipolar sEMG. However, not only potentials from the muscle of interest reach the recording site, but also those from neighboring muscles. This phenomenon is referred to as “crosstalk”. The potential presence of crosstalk is a major challenge for sEMG in the assessment of muscular coordination, as it prevents a confident conclusion regarding the existence of coactivation of antagonistic muscles. The practical applicability of sEMG to the assessment of muscular coordination requires therefore the availability of a methodology to effectively discriminate the effects of crosstalk from the actual signals recorded from the targeted muscles.

METHODS
The quantification of coactivation demands in a first step a good understanding of the physical nature of crosstalk. This phenomenon occurs as a result of the volume conduction properties of biological tissue, which are highly dependent on personal specific anatomical features as well as on complex, to considerable extent inhomogeneous and individual tissue characteristics. The contribution of the individual signal sources to the recorded signal is therefore highly specific for each patient and in most cases not separately quantifiable. Since the presence of crosstalk is to a large degree affected by these specific properties, it can be assumed that crosstalk is also an individual feature.

The “Crosstalk Risk Factor” (CRF) is a person-specific probability for the occurrence of crosstalk. It combines the above mentioned individual, non quantifiable parameters to one objective quantity using a fuzzy inference machine on recorded sEMG data acquired from a healthy antagonistic muscle pair. As the likelihood of the occurrence of crosstalk for each patient is an individual quantity in the case of brachial plexus lesion, information from sEMG signals derived from the healthy side of the patient is used. Furthermore, combining the CCR with the cross-correlation of the measured sEMG signals between the antagonistic muscles, the “Confidence value for Coactivation” (CCA) for the affected side is calculated. The CCA was calculated in a case study with a group of 20 children with an age range of 5-10 years. From a medical standpoint, for 15 of the 20 children muscular coactivation due to a plexus lesion was pointed out as a probable cause for the observed limitations. The other 5 children constituted a healthy control group.

The data needed for the movement and muscular coordination analysis was gathered using both a 3D motion capture system (Vicon 370) and sEMG. Measurements included the recording of conventional bipolar sEMG of M. biceps brachii and M. triceps brachii according to the SENIAM standard. The actual movements from the patient are reconstructed from the marker trajectories acquired by the motion analysis system. By using a biomechanical
model of the upper extremity [4], a complete set of joint angles along the motion chain is obtained.

RESULTS AND DISCUSSION
Figure 1 shows the results obtained exemplarily for a patient for one of several test movements, “the cookie test”, which features an elbow flexion. With values for the CRF=0.17 and CCA=0.980, it can be concluded confidently that the activity seen in the sEMG from the affected side is due to coactivation instead of crosstalk. Consequently it can be clearly observed that the mechanical performance of the movement is greatly affected by the occurrence of pathological coactivation.

Figure 1: Comparison of the sEMG data of the healthy and affected upper extremity of a patient affected by brachial plexus lesion (CRF=0.17; CCA=0.980) during flexion/extension of the elbow joint.

In the case study, the intra-individual values of the CRF remained nearly constant between several measurements in the course of a year, supporting the validity of the methodology based on a person-specific likelihood for crosstalk. Additionally, as no significant difference between the value of the CRF of patients and control group members was found (Figure 2), no relationship between the CRF alone and a possible medical diagnosis can be established. Nevertheless, by combining information from the CRF with the sEMG data from the antagonistic muscles of the affected side, the calculated CCA allows a successful discrimination between crosstalk and actual coactivation. As shown in Figure 2, within the group of healthy subjects a low probability (<0.4) of coactivation was calculated. In contrast, the calculated probability for coactivation in the measured sEMG from the affected side of the subjects suffering from brachial plexus lesion was very high (>0.8). A double-sided t-test using a confidence-level <0.01 supported the fact that the difference between the healthy and affected subjects with respect to the calculated CCA is significant.

Some of the patients were treated with Botulinum Toxin (Botox) as a means to reduce the pathological muscular coactivation[1]. For this group of patients both the CRF and the CCA were calculated along different sessions, both before and after the application of Botox. As expected, the CRF showed only small variations (exemplarily for a patient CRF_{t1}=0.17, CRF_{Botox}=0.09, CRF_{t2}=0.10), as it is calculated based on the anatomy of the healthy, untreated side. In contrast, the CCA reflected the desired effect of coactivation decline, as well as its increase after the temporary effects of Botox fade (CCA_{t1}=0.980, CCA_{Botox}=0.515, CCA_{t2}=0.876, CCA_{t3}=0.980).

Figure 2: Summary of the results of the Crosstalk Risk Factor (CRF) and the Confidence value for Coactivation (CCA) for affected and healthy subjects.

CONCLUSIONS
The Crosstalk Risk Factor, taking into account individual anatomical and histological characteristics, allows a quantification of the individual affinity for crosstalk. Additionally, the introduced Confidence value for Coactivation proved itself as a powerful tool for the diagnosis of pathological coactivation.

The results show that the CCA is related to the mechanical performance of movement; therefore by its application the validity of a diagnosis performed by means of muscular coordination analysis through sEMG is greatly improved. These results were successfully validated on a case study with patients affected by obstetric brachial plexus lesion.

REFERENCES