



ISB 2013
BRAZIL

XXIV CONGRESS OF THE INTERNATIONAL
SOCIETY OF BIOMECHANICS

XV BRAZILIAN CONGRESS
OF BIOMECHANICS

The Impact of Angular Velocity on Muscular Coordination in Physiological and Spastic Movements

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SUMMARY

To assess the impact of angular velocity on muscular coordination in healthy subjects and patients with spasticity, physiological and pathological movements need to be compared.

In that context, the impact of angular velocity on muscular coordination of flexion and extension of the elbow was assessed in 15 healthy and 5 spastic subjects. Synchronously to surface Electromyography (sEMG) of biceps brachii, brachioradialis and triceps brachii, elbow flexion and extension angles, as well as angular velocities of the performed movements, were recorded. During the measuring procedure, the angular velocity was gradually increased with the help of a real-time visual feedback. For increasing angular velocities a change of muscular coordination of patients and healthy subjects was observed. However, for spastic patients, muscular coordination patterns were determined, which significantly differ from the physiological patterns with higher intensity for increasing angular velocities.

INTRODUCTION

Everybody moves at his own pace. Thereby the interaction of muscles contributing to a functional movement, the muscular coordination, depends on numerous factors. The impact of different angular velocities plays an important role if the effectiveness of physiological and pathological, e.g. spastic movements is regarded.

In physiological movements antagonistic muscle groups are activated in a balanced manner. The contributing muscles interact to target the intended velocity performance. In contrast, spastic movements can be expressed in form of an ineffective counteraction of antagonistic muscles.

In 1980, Lance described spasticity as a velocity dependent increase in tonic stretch reflex [1]. Following a literature review, Malhotra pronounced in 2009, that the term spasticity is still inconsistently defined and spasticity measures often do not correspond to the description of the key clinical features [2]. There is no measuring procedure, which quantitatively assesses spasticity in different angular velocities. At the same time, the relation of angular velocity

in free voluntary movements on muscular coordination is unknown in healthy subjects as well.

However, muscle stretch velocity correlates with the angular velocity. To evaluate the effect of muscle stretch velocity on healthy subjects and spastic patients the muscular coordination should be regarded in the context of all muscles contributing to the intended movement. Thus, physiological and pathological movements need to be compared in different angular velocities.

METHODS

Initially muscular coordination of elbow flexion and extension was assessed in 15 healthy subjects and 5 patients with spasticity. To individually assess muscular coordination in different velocities a quantitative measure for muscular coordination synchronized to angular velocity is required. The implemented measuring procedure allows free voluntary movements and consists of three components (Figure 1).

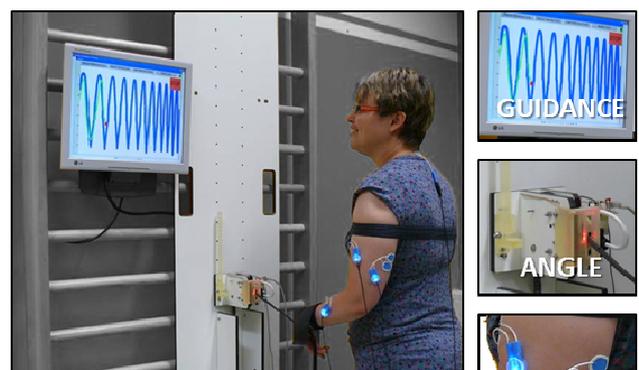


Figure 1: Angular velocities are increased with the help of a visual feedback, while joint angles as well as sEMG signals are recorded.

In order to quantitatively analyze muscular coordination bipolar sEMG is utilized. The sEMG electrodes are placed

on the biceps brachii, triceps brachii and brachioradialis according to the SENIAM recommendations.

Synchronously to sEMG, elbow flexion and extension angles, as well as angular velocities of the performed movements, are recorded. The angular velocity is gradually increased during the measuring procedure. Thereby compliance of targeted to performed movement is controlled with the help of a real-time visual feedback.

As a result, the synchronous recording of sEMG, performed elbow flexion and extension angle and performed angular velocity leads to the assessment of muscular coordination in different angular velocities.

RESULTS AND DISCUSSION

In order to evaluate the impact of different angular velocities, every single measuring trial is split into several movement cycles with one flexion and extension phase each. Thereby one movement cycle starts from full extension of the elbow and contains the dynamical movement to reach full flexion and range back to full extension.

In all 15 healthy subjects characteristic muscular coordination patterns were observed, which correlated with the individual performed angular velocity. For slow angular velocities ($<39\pm 16$ deg/sec), the brachioradialis tends to be activated for small flexion angles, whereas the biceps brachii is activated in higher flexion angles as well (Figure 2A). For fast angular velocities ($>72\pm 25$ deg/sec), the brachioradialis approaches the biceps activation pattern in higher flexion angles (Figure 2B). In all velocity performances, both flexors help to stabilize the joint at the end of the extension phase. The extensor triceps brachii is activated in the extension phase only.

All five patients with spasticity showed muscular coordination patterns, which individually differ from the described physiological coordination patterns in slow and especially in fast movements. For slow angular velocities the unbalanced muscular coordination was individually expressed. Thereby, an increased activity of antagonistic muscles was observed, which individually appeared in flexion or extension phases. Additionally, the described physiological activation of biceps brachii and brachioradialis in different flexion angles could not be found in spastic patients (Figure 2C). For fast angular velocities two types of distinctive muscular coordination patterns were observed, which occurred in different combinations. One individual distinctive pattern in fast flexion and extension of the elbow can be described in an increase in the baseline of at least one sEMG signal. Furthermore, additional peaks of the enveloped sEMG signal of triceps during the flexion phase, or additional peaks of biceps brachii or brachioradialis during the entire extension phase were observed (Figure 2D).

In both healthy and spastic subjects, the change of muscular coordination patterns occurred in different individual angular velocity limits.

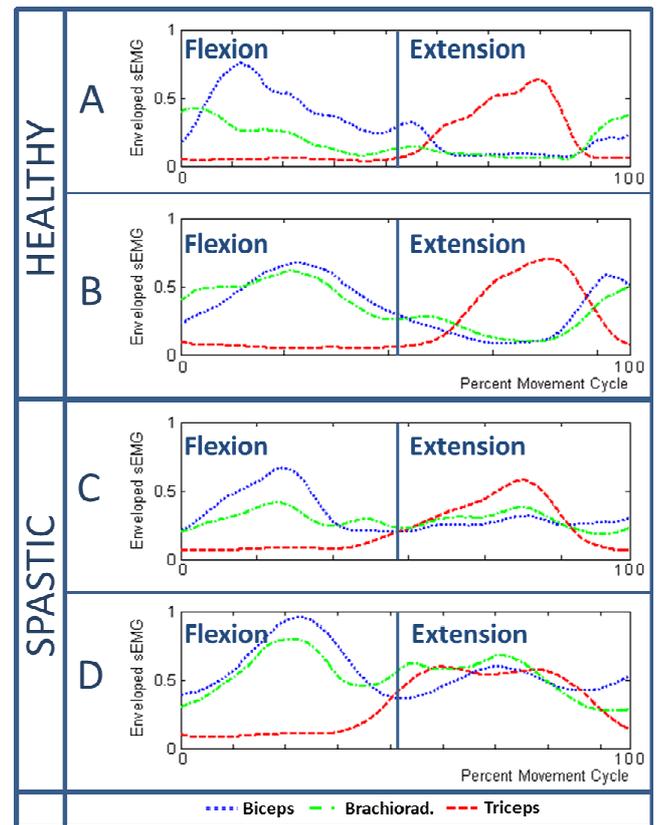


Figure 2: Muscular coordination of flexion and extension of the elbow in two individual different angular velocities of a healthy subject (A: 48 deg/sec, B: 118 deg/sec) and a patient with spasticity (C: 41 deg/sec, D: 80 deg/sec).

CONCLUSION

Different angular velocities affect the muscular coordination of both, patients and healthy subjects. However, this impact of angular velocity on physiological and spastic movements occurs in different ways.

Characteristic patterns of physiological muscular coordination were detected, which depend on the conducted angular velocities. In contrast to healthy subjects, spastic patients showed an individual combination of distinctive patterns of altered muscular coordination, especially for high angular velocities.

The individual assessment of muscle stretch velocity dependent alterations of muscular coordination can be a first step in order to classify different types of spasticity.

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