Interpretation of the muscular co-ordination pattern supported by fuzzy logic

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Introduction

The information about the co-ordination pattern of different muscles or muscle groups is of high relevance not only in the treatment of movement disorders but also in other fields e.g. rehabilitation medicine or sport sciences. Abnormal muscular co-ordination patterns often hinder the performance of an effective movement and results frequently in serious functional impairments.

Although the abnormal muscular co-ordination pattern is often the reason, in clinical praxis the characterisation of the movement deficiencies is still based on the analysis of the mechanics of the movement. 3D movement analysis has been turned out to be a proper tool to achieve objective data about kinematic, kinetic, forces or power of the movement but the methodology does not yield any information about the muscular co-ordination pattern. Surface-EMG signals detected simultaneous at different muscles are suitable to assess the muscular co-ordination pattern and would provide the needed information, but the interpretation of the surface-EMG signals is time consuming and often difficult even for experienced users. This is why surface-EMG is so far not been introduced to clinical routine (Winter 1984, Winter 1987).

This paper presents a new approach based on fuzzy-logic which supports the interpretation of the surface-EMG signals and facilitates the assessment of the muscular co-ordination pattern. This methodology contributes to utilise surface-EMG and the information about the muscular co-ordination pattern in clinical routine. The procedure is exemplified by the muscular co-ordination pattern of the ankle joint movement during gait in healthy volunteers and patients suffering from spasticity in gait.

Methods

To support the interpretation of the surface-EMG signals in order to get the information about the effectiveness of the muscular co-ordination pattern, an expert-system has been created which is based on the fuzzy-inference-method. This method makes the management of uncertain, complex, logical connections with linguistic instruments possible. In a first approach the methodology has been exemplified by the muscular co-ordination pattern during gait. Thus, the surface-EMG signals of the most relevant muscles during ankle movement (tibialis anterior, soleus and gastrocnemius) have been validated by the expert system. The knowledge-base of the expert system takes into account that in those cases in which agonist and antagonist are synchronously active the movement of the joint is not effective. Those cases in which the co-activation is needed to stabilise the joint are excepted. The evaluation of the surface-EMG signals by the fuzzy-inference regards the level of activation of each muscle, the contribution of the different muscle to the resulting movement and the moment of activation within the gait cycle. This information results in 11 rules e.g. “If the tibialis anterior and the gastrocnemius are simultaneous active, than the movement of the ankle joint is not effective”. Each rule is weighted according to its relevance for the ankle movement. The resulting output measure of the fuzzy-system has been called “Effectiveness” of ankle joint movement. It indicates to which extent and at what periods of time the muscular co-ordination pattern yields an effective movement of the ankle. Figure 1 schematises the development of the different rules and their outcome measure.
Conventional bipolar surface-EMG has been recorded simultaneously from the tibialis anterior, the soleus and the gastrocnemius medialis muscle according to the SENIAM recommendations (SENIAM 1999). EMG data have been rectified and smoothed by a 10 Hz high pass filter. For each muscle different EMG-sweeps have been synchronised to the gait cycle, which has been detected by food-switches. The EMG-sweeps have been averaged and normalised to the maximum EMG amplitude appearing in each EMG envelope. The normalised EMG envelopes of the different muscles have been used as the input parameters for the expert system.

Results & Discussion
The expert-system has been verified at the ankle movement of healthy volunteers and patients suffering from spasticity in gait. 20 Patients aged between 5 and 12 years and 10 adult volunteers have been evaluated with the fuzzy-system.
Figure 2 shows the results of the fuzzy-logic based interpretation of the muscular co-ordination pattern of a healthy volunteer and a patient suffering from spasticity in gait. In the case of the healthy volunteer the fuzzy system shows that the effectiveness of the ankle joint motion is high during the complete gait cycle. This is due to a normal muscular co-ordination pattern where agonistic and antagonistic muscles work in an effective way. In contrast to the healthy case in patients with spasticity the effectiveness of the motion is not as good as in healthy ones. Especially in the beginning of the stance phase and at the end of the swing phase the muscular co-ordination pattern induces a motion which effectiveness is poor. In patients with less pronounced spasticity the effectiveness of the motion can increase to normal values again. The degree of loss of effectiveness and the time of recovery typical for each patient corresponds to the degree of spasticity.

The example of the ankle joint motion in spastic and healthy gait shows that the interpretation of the muscular co-ordination pattern detected with surface-EMG can be supported by the fuzzy-inference methodology. This is an essential prerequisite for the use of the information about the muscular co-ordination in clinical routine. The example of the relatively simple ankle movement demonstrates the principles’ feasibility. However, the structure of the methodology allows to extend it to more complex movements with a higher number of joints and muscles involved. This opens new information about the movement not only for the treatment of patients with movement disorders.

References

